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(71) Applicant (for all designated States except US): **SHELL OIL COMPANY** [US/US]; 910 Louisiana Street, Houston, TX 77252-2463 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **BRISCO, David, P.** [US/US]; 405 Westridge Drive, Duncan, OK 73533 (US). **ZWALD, Edwin, A.** [US/US]; Memorial Drive #110, Houston, TX 77024 (US). **DAIGLE, Chan** [US/US]; 3017 E. Elm Circle, Katy, TX 77493 (US). **NOEL, Gregory, M.** [US/US]; 611 Whitehurst, Katy, TX 77450 (US). **DEAN, William, J.** [US/US]; 22602 Crescent Cove Court,

Katy, TX 77494 (US). **FILIPPOV, Andrei, Gregory** [US/US]; 2606 Hidden Shore Drive, Katy, TX 77450 (US). **NIDA, Ronald, D.** [US/US]; 31618 Fulshear Creek Trail, Fulshear, TX 77441 (US). **COOK, Robert, Lance** [US/US]; 934 Caswell Court, Katy, TX 77450 (US). **RING, Lev** [RU/US]; 14126 Heatherhill Place, Houston, TX 77077 (US). **WADELL, Kevin, K.** [US/US]; 11007 Sprucedale Court, Houston, TX 77070 (US). **STEPHENSON, William, Rusty** [US/US]; 14220 Park Row #1415, Houston, TX 77084 (US). **GUSEVIK, Rune, T.** [US/US]; 15206 Chimney Hill, Houston, TX 77095 (US).

(74) Agents: **BECKER, Jeffrey, M.** et al.; Haynes and Boone L.L.P., 1000 Louisiana, Suite 4300, Houston, TX 77002 (US).

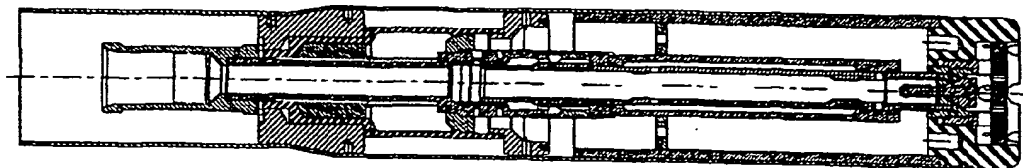
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(54) Title: LINER HANGER WITH SLIDING SLEEVE VALVE

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(57) Abstract: An apparatus and method for forming or repairing a wellbore casing, a pipeline, or a structural support is disclosed. An expandable tubular member (20a) is radially expanded and plastically deformed by an expansion cone (18) that is displaced by hydraulic pressure. Before or after the radial expansion of the expandable tubular member (20a), sliding sleeve valve (42) within the apparatus permit a hardenable fluidic sealing material to be injected into an annulus between the expandable tubular member (20a) and a preexisting structure.

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LINER HANGER WITH SLIDING SLEEVE VALVE
Cross Reference To Related Applications

This application claims the benefit of the filing date of U.S. provisional patent application serial number 60/233,638, attorney docket number 25791.47, filed on 9/18/2000, the disclosure of which is incorporated herein by reference.

- 5 This application is related to the following co-pending applications: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent
- 10 application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on
- 15 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) U.S. patent application serial no. _____, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no.
- 20 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S.
- 25 provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. _____, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no.
- 30 _____, attorney docket no. 25791.45, filed on 7/28/2000, and (19) U.S. provisional patent application serial no. _____, attorney docket no.

25791.46, filed on 7/28/2000. Applicants incorporate by reference the disclosures of these applications.

Background of the Invention

This invention relates generally to wellbore casings, and in particular to
5 wellbore casings that are formed using expandable tubing.

Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a
10 casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are
15 provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of
20 drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

The present invention is directed to overcoming one or more of the
25 limitations of the existing procedures for forming wellbores.

Summary of the Invention

According to one aspect of the invention, a method of forming a wellbore casing within a borehole within a subterranean formation is provided that includes positioning an expandable tubular member within the borehole,
30 injecting fluidic materials into the expandable tubular member, fluidically isolating a first region from a second region within the expandable tubular member, fluidically coupling the first and second regions, injecting a hardenable

fluidic sealing material into the expandable tubular member, fluidically

decoupling the first and second regions, and injecting a non-hardenable fluidic material into the expandable tubular member to radially expand the tubular member.

5 According to another aspect of the present invention, an apparatus for forming a wellbore casing within a borehole within a subterranean formation is provided that includes means for positioning an expandable tubular member within the borehole, means for injecting fluidic materials into the expandable tubular member, means for fluidically isolating a first region from a second
10 region within the expandable tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand the tubular
15 member.

 According to another aspect of the present invention, a method of forming a wellbore casing within a borehole within a subterranean formation is provided that includes positioning an expandable tubular member within the borehole, injecting fluidic materials into the expandable tubular member,
20 fluidically isolating a first region from a second region within the expandable tubular member, injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member, fluidically coupling the first and second regions, injecting a hardenable fluidic sealing material into the expandable tubular member, fluidically
25 decoupling the first and second regions, and injecting a non-hardenable fluidic material into the expandable tubular member to radially expand another portion of the tubular member.

 According to another aspect of the present invention, an apparatus for forming a wellbore casing within a borehole within a subterranean formation is
30 provided that includes means for positioning an expandable tubular member within the borehole, means for injecting fluidic materials into the expandable tubular member, means for fluidically isolating a first region from a second

region within the expandable tubular member, means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand another portion of the tubular member.

According to another aspect of the present invention, an apparatus for forming a wellbore casing within a borehole within a subterranean formation is provided that includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having first and second throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve.

According to another aspect of the present invention, an apparatus for forming a wellbore casing in a borehole in a subterranean formation is provided that includes means for radially expanding an expandable tubular member and means for injecting a hardenable fluidic sealing material into an annulus between the expandable tubular member and the borehole.

According to another aspect of the present invention, a method of operating an apparatus for forming a wellbore casing within a borehole within a subterranean formation is provided. The apparatus includes a first annular support member defining a first fluid passage and one or more first radial

5 passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third

10 fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an

15 annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve. The method includes positioning the apparatus within the borehole,

20 injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular

25 sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand the expandable tubular member.

According to another aspect of the present invention, a method of

30 operating an apparatus for forming a wellbore casing within a borehole within a subterranean formation is provided in which the apparatus includes a first annular support member defining a first fluid passage and one or more first

radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve. The method includes positioning the apparatus within the borehole, injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, injecting a non-hardenable fluidic material through the first fluid passages and the first radial passages and pressure sensitive valves into the annular region to radially expand a portion of the expandable tubular member, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand another portion of the expandable tubular member.

According to one aspect of the invention, a method of coupling an expandable tubular member to a preexisting structure is provided that includes positioning an expandable tubular member within the preexisting structure, injecting fluidic materials into the expandable tubular member, fluidically isolating a first region from a second region within the expandable tubular

member, fluidically coupling the first and second regions, injecting a hardenable
fluidic sealing material into the expandable tubular member, fluidically
decoupling the first and second regions, and injecting a non-hardenable fluidic
material into the expandable tubular member to radially expand the tubular
5 member.

According to another aspect of the present invention, an apparatus for
coupling an expandable tubular member to a preexisting structure is provided
that includes means for positioning the expandable tubular member within the
preexisting structure, means for injecting fluidic materials into the expandable
10 tubular member, means for fluidically isolating a first region from a second
region within the expandable tubular member, means for fluidically coupling the
first and second regions, means for injecting a hardenable fluidic sealing
material into the expandable tubular member, means for fluidically decoupling
the first and second regions, and means for injecting a non-hardenable fluidic
15 material into the expandable tubular member to radially expand the tubular
member.

According to another aspect of the present invention, a method of
coupling an expandable tubular member to a preexisting structure is provided
that includes positioning the expandable tubular member within the
20 preexisting structure, injecting fluidic materials into the expandable tubular
member, fluidically isolating a first region from a second region within the
expandable tubular member, injecting a non-hardenable fluidic material into
the expandable tubular member to radially expand at least a portion of the
tubular member, fluidically coupling the first and second regions, injecting a
25 hardenable fluidic sealing material into the expandable tubular member,
fluidically decoupling the first and second regions, and injecting a non-hardenable
fluidic material into the expandable tubular member to radially expand another
portion of the tubular member.

According to another aspect of the present invention, an apparatus for
30 coupling an expandable tubular member to a preexisting structure is provided
that includes means for positioning the expandable tubular member within the
preexisting structure, means for injecting fluidic materials into the expandable

tubular member, means for fluidically isolating a first region from a second region within the expandable tubular member, means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand another portion of the tubular member.

10 According to another aspect of the present invention, an apparatus for coupling an expandable tubular member to a preexisting structure is provided that includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first
15 annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having first and second throat passages, defining second and third
20 radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular
25 region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve.

According to another aspect of the present invention, an apparatus for coupling an expandable tubular member to a preexisting structure is provided
30 that includes means for radially expanding an expandable tubular member and means for injecting a hardenable fluidic sealing material into an annulus between the expandable tubular member and the borehole.

According to another aspect of the present invention, a method of operating an apparatus for coupling an expandable tubular member to a preexisting structure is provided. The apparatus includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve. The method includes positioning the apparatus within the preexisting structure, injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand the expandable tubular member.

According to another aspect of the present invention, a method of operating an apparatus for coupling an expandable tubular member to a preexisting structure is provided in which the apparatus includes a first annular support member defining a first fluid passage and one or more first radial

passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve. The method includes positioning the apparatus within the preexisting structure, injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, injecting a non-hardenable fluidic material through the first fluid passages and the first radial passages and pressure sensitive valves into the annular region to radially expand a portion of the expandable tubular member, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand another portion of the expandable tubular member.

Brief Description of the Drawings

Figs. 1 and 1a-1c are cross sectional illustrations of an embodiment of a liner hanger assembly including a sliding sleeve valve assembly.

Figs. 2a-2b is a flow chart illustration of an embodiment of a method for forming a wellbore casing using the liner hanger assembly of Figs. 1 and 1a-1c.

Figs. 3a-3c are cross sectional illustrations of the placement of the liner hanger assembly of Figs. 1 and 1a-1c into a wellbore.

Figs. 4a-4c are cross sectional illustrations of the injection of a fluidic materials into the liner hanger assembly of Figs. 3a-3c.

5 Figs. 5a-5c are cross sectional illustrations of the placement of a bottom plug into the liner hanger assembly of Figs. 4a-4c.

Figs. 6a-6c are cross sectional illustrations of the downward displacement of sliding sleeve of the liner hanger assembly of Figs. 5a-5c.

10 Figs. 7a-7c are cross sectional illustrations of the injection of a hardenable fluidic sealing material into the liner hanger assembly of Figs. 6a-6c that bypasses the plug.

Figs. 8a-8c are cross sectional illustrations of the placement of a top plug into the liner hanger assembly of Figs. 7a-7c.

15 Figs. 9a-9c are cross sectional illustrations of the upward displacement of sliding sleeve of the liner hanger assembly of Figs. 8a-8c.

Figs. 10a-10c are cross sectional illustrations of the injection of a pressurized fluidic material into the liner hanger assembly of Figs. 9a-9c in order to radially expand and plastically deform the expansion cone launcher.

20 Figs. 11a-11b is a flow chart illustration of an alternative embodiment of a method for forming a wellbore casing using the liner hanger assembly of Figs. 1 and 1a-1c.

25 Figs. 12a-12c are cross sectional illustrations of the injection of a pressurized fluidic material into the liner hanger assembly of Figs. 5a-5c in order to at least partially radially expand and plastically deform the expansion cone launcher.

Figs. 13a-13c are cross sectional illustrations of the downward displacement of the sliding sleeve of the liner hanger assembly of Figs. 12a-12c.

30 Figs. 14a-14c are cross sectional illustrations of the injection of a hardenable fluidic sealing material through the liner hanger assembly of Figs. 13a-13c.

Figs. 15a-15c are cross sectional illustrations of the injection and placement of a top plug into the liner hanger assembly of Figs. 14a-14c.

Figs. 16a-16c are cross sectional illustrations of the upward displacement of the sliding sleeve of the liner hanger assembly of Figs. 15a-15c.

Figs. 17a-17c are cross sectional illustrations of the injection of a pressurized fluidic material into the liner hanger assembly of Figs. 16a-16c in order to complete the radial expansion of the expansion cone launcher.

Figs. 18, 18a, 18b, and 18c are cross sectional illustrations of an alternative embodiment of a liner hanger assembly including a sliding sleeve valve assembly.

Figs. 19a-19b is a flow chart illustration of an embodiment of a method for forming a wellbore casing using the liner hanger assembly of Figs. 18 and 18a-18c.

Figs. 20a-20c are cross sectional illustrations of the placement of the liner hanger assembly of Figs. 18 and 18a-18c into a wellbore.

Figs. 21a-21c are cross sectional illustrations of the injection of a fluidic materials into the liner hanger assembly of Figs. 20a-20c.

Figs. 22a-22c are cross sectional illustrations of the placement of a bottom plug into the liner hanger assembly of Figs. 21a-21c.

Figs. 23a-23c are cross sectional illustrations of the downward displacement of sliding sleeve of the liner hanger assembly of Figs. 22a-22c.

Figs. 24a-24c are cross sectional illustrations of the injection of a hardenable fluidic sealing material into the liner hanger assembly of Figs. 23a-23c that bypasses the bottom plug.

Figs. 25a-25c are cross sectional illustrations of the placement of a top plug into the liner hanger assembly of Figs. 24a-24c.

Figs. 26a-26c are cross sectional illustrations of the upward displacement of sliding sleeve of the liner hanger assembly of Figs. 25a-25c.

Figs. 27a-27c are cross sectional illustrations of the injection of a pressurized fluidic material into the liner hanger assembly of Figs. 26a-26c in order to radially expand and plastically deform the expansion cone launcher.

Figs. 28a-28b is a flow chart illustration of an alternative embodiment of a method for forming a wellbore casing using the liner hanger assembly of Figs. 18 and 18a-18c.

Figs. 29a-29c are cross sectional illustrations of the injection of a pressurized fluidic material into the liner hanger assembly of Figs. 22a-22c in order to at least partially radially expand and plastically deform the expansion cone launcher.

5 Figs. 30a-30c are cross sectional illustrations of the downward displacement of the sliding sleeve of the liner hanger assembly of Figs. 29a-29c.

Figs. 31a-31c are cross sectional illustrations of the injection of a hardenable fluidic sealing material through the liner hanger assembly of Figs. 30a-30c.

10 Figs. 32a-32c are cross sectional illustrations of the injection and placement of a top plug into the liner hanger assembly of Figs. 31a-31c.

Figs. 33a-33c are cross sectional illustrations of the upward displacement of the sliding sleeve of the liner hanger assembly of Figs. 32a-32c.

15 Figs. 34a-34c are cross sectional illustrations of the injection of a pressurized fluidic material into the liner hanger assembly of Figs. 33a-33c in order to complete the radial expansion of the expansion cone launcher.

Detailed Description

A liner hanger assembly having sliding sleeve bypass valve is provided. In several alternative embodiments, the liner hanger assembly provides a
20 method and apparatus for forming or repairing a wellbore casing, a pipeline or a structural support.

Referring initially to Figs. 1, 1a, 1b, and 1c, an embodiment of a liner hanger assembly 10 includes a first tubular support member 12 defining an internal passage 12a that includes a threaded counterbore 12b at one end, and a
25 threaded counterbore 12c at another end. A second tubular support member 14 defining an internal passage 14a includes a first threaded portion 14b at a first end that is coupled to the threaded counterbore 12c of the first tubular support member 12, a stepped flange 14c, a counterbore 14d, a threaded portion 14e, and internal splines 14f at another end. The stepped flange 14c of the second
30 tubular support member 14 further defines radial passages 14g, 14h, 14i, and 14j. A third tubular support member 16 defining an internal passage 16a for receiving the second tubular support member 14 includes a first flange 16b, a

second flange 16c, a first counterbore 16d, a second counterbore 16e having an internally threaded portion 16f, and an internal flange 16g. The second flange 16c further includes radial passages 16h and 16i.

An annular expansion cone 18 defining an internal passage 18a for receiving the second and third tubular support members, 14 and 16, includes a counterbore 18b at one end, and a counterbore 18c at another end for receiving the flange 16b of the second tubular support member 16. The annular expansion cone 18 further includes an end face 18d that mates with an end face 16j of the flange 16c of the second tubular support member 16, and an exterior surface 18e having a conical shape in order to facilitate the radial expansion of tubular members. A tubular expansion cone launcher 20 is movably coupled to the exterior surface 18e of the expansion cone 18 and includes a first portion 20a having a first wall thickness, a second portion 20b having a second wall thickness, a threaded portion 20c at one end, and a threaded portion 20d at another end. In a preferred embodiment, the second portion 20b of the expansion cone launcher 20 mates with the conical outer surface 18e of the expansion cone 18. In a preferred embodiment, the second wall thickness is less than the first wall thickness in order to optimize the radial expansion of the expansion cone launcher 20 by the relative axial displacement of the expansion cone 18. In a preferred embodiment, one or more expandable tubulars are coupled to the threaded connection 20c of the expansion cone launcher 20. In this manner, the assembly 10 may be used to radially expand and plastically deform, for example, thousands of feet of expandable tubulars.

An annular spacer 22 defining an internal passage 22a for receiving the second tubular support member 14 is received within the counterbore 18b of the expansion cone 18, and is positioned between an end face 12d of the first tubular support member 12 and an end face of the counterbore 18b of the expansion cone 18. A fourth tubular support member 24 defining an internal passage 24a for receiving the second tubular support member 14 includes a flange 24b that is received within the counterbore 16d of the third tubular support member 16. A fifth tubular support member 26 defining an internal passage 26a for receiving the second tubular support member 14 includes an

internal flange 26b for mating with the flange 14c of the second tubular support member and a flange 26c for mating with the internal flange 16g of the third tubular support member 16.

An annular sealing member 28, an annular sealing and support member 30, an annular sealing member 32, and an annular sealing and support member 34 are received within the counterbore 14d of the second tubular support member 14. The annular sealing and support member 30 further includes a radial opening 30a for supporting a rupture disc 36 within the radial opening 14g of the second tubular support member 14 and a sealing member 30b for sealing the radial opening 14h of the second tubular support member. The annular sealing and support member 34 further includes sealing members 34a and 34b for sealing the radial openings 14i and 14j, respectively, of the second tubular support member 14. In an exemplary embodiment, the rupture disc 36 opens when the operating pressure within the radial opening 30b is about 1000 to 5000 psi. In this manner, the rupture disc 36 provides a pressure sensitive valve for controlling the flow of fluidic materials through the radial opening 30a. In several alternative embodiments, the assembly 10 includes a plurality of radial passages 30a, each with corresponding rupture discs 36.

A sixth tubular support member 38 defining an internal passage 38a for receiving the second tubular support member 14 includes a threaded portion 38b at one end that is coupled to the threaded portion 16f of the third tubular support member 16 and a flange 38c at another end that is movably coupled to the interior of the expansion cone launcher 20. An annular collet 40 includes a threaded portion 40a that is coupled to the threaded portion 14e of the second tubular support member 14, and a resilient coupling 40b at another end.

An annular sliding sleeve 42 defining an internal passage 42a includes an internal flange 42b, having sealing members 42c and 42d, and an external groove 42e for releasably engaging the coupling 40b of the collet 40 at one end, and an internal flange 42f, having sealing members 42g and 42h, at another end. During operation the coupling 40b of the collet 40 may engage the external groove 42e of the sliding sleeve 42 and thereby displace the sliding sleeve in the longitudinal direction. Since the coupling 40b of the collet 40 is

resilient, the collet 40 may be disengaged or reengaged with the sliding sleeve 42. An annular valve member 44 defining an internal passage 44a, having a first throat 44aa and a second throat 44ab, includes a flange 44b at one end, having external splines 44c for engaging the internal splines 14f of the second tubular support member 14, a first set of radial passages, 44da and 44db, a second set of radial passages, 44ea and 44eb, and a threaded portion 44f at another end. The sliding sleeve 42 and the valve member 44 define an annular bypass passage 46 that, depending upon the position of the sliding sleeve 42, permits fluidic materials to flow from the passage 44 through the first radial passages, 44da and 44db, the bypass passage 46, and the second radial passages, 44ea and 44eb, back into the passage 44. In this manner, fluidic materials may bypass the portion of the passage 44 between the first and second radial passages, 44ea, 44eb, 44da, and 44db. Furthermore, the sliding sleeve 42 and the valve member 44 together define a sliding sleeve valve for controllably permitting fluidic materials to bypass the intermediate portion of the passage 44a between the first and second passages, 44da, 44db, 44ea, and 44eb. During operation, the flange 44b limits movement of the sliding sleeve 42 in the longitudinal direction.

In a preferred embodiment, the collet 40 includes a set of couplings 40b such as, for example, fingers, that engage the external groove 42e of the sliding sleeve 42. During operation, the collet couplings 40b latch over and onto the external groove 42e of the sliding sleeve 42. In a preferred embodiment, a longitudinal force of at least about 10,000 to 13,000 lbf is required to pull the couplings 40b off of, and out of engagement with, the external groove 42e of the sliding sleeve 42. In an exemplary embodiment, the application of a longitudinal force less than about 10,000 to 13,000 lbf indicates that the collet couplings 40b are latched onto the external shoulder of the sliding sleeve 42, and that the sliding sleeve 42 is in the up or the down position relative to the valve member 44. In a preferred embodiment, the collet 40 includes a conventional internal shoulder that transfers the weight of the first tubular support member 12 and expansion cone 18 onto the sliding sleeve 42. In a

preferred embodiment, the collet 40 further includes a conventional set of internal lugs for engaging the splines 44c of the valve member 44.

An annular valve seat 48 defining a conical internal passage 48a for receiving a conventional float valve element 50 includes an annular recess 48b, 5 having an internally threaded portion 48c for engaging the threaded portion 44f of the valve member 44, at one end, and an externally threaded portion 48d at another end. In an alternative embodiment, the float valve element 50 is omitted. An annular valve seat mounting element 52 defining an internal passage 52a for receiving the valve seat 48 and float valve 50 includes an 10 internally threaded portion 52b for engaging the externally threaded portion 48d of the valve seat 48, an externally threaded portion 52c, an internal flange 52d, radial passages, 52ea and 52eb, and an end member 52f, having axial passages, 52fa and 52fb.

A shoe 54 defining an internal passage 54a for receiving the valve seat 15 mounting element 52 includes a first annular recess 54b, having an externally threaded portion 54c, and a second annular recess 54d, having an externally threaded portion 54e for engaging the threaded portion 20d of the expansion cone launcher 20, at one end, a first threaded counterbore 54f for engaging the threaded portion 52c of the of the mounting element, and a second counterbore 20 54g for mating with the end member 52f of the mounting element. In a preferred embodiment, the shoe 54 is fabricated from a ceramic and/or a composite material in order to facilitate the subsequent removal of the shoe by drilling. A seventh tubular support member 56 defining an internal passage 56a for receiving the sliding sleeve 42 and the valve member 44 is positioned 25 within the expansion cone launcher 20 that includes an internally threaded portion 56b at one end for engaging the externally threaded portion 54c of the annular recess 54b of the shoe 54. In a preferred embodiment, during operation of the assembly, the end of the seventh tubular support member 56 limits the longitudinal movement of the expansion cone 18 in the direction of the shoe 54 30 by limiting the longitudinal movement of the sixth tubular support member 38. An annular centralizer 58 defining an internal passage 58a for movably supporting the sliding sleeve 42 is positioned within the seventh tubular

support member 56 that includes axial passages 58b and 58c. In a preferred embodiment, the centralizer 58 maintains the sliding sleeve 42 and valve member 44 in a central position within the assembly 10.

Referring to Figs. 2a-2b, during operation, the assembly 10 may be used to form or repair a wellbore casing by implementing a method 200 in which, as illustrated in Figs. 3a-3c, the assembly 10 may initially be positioned within a wellbore 100 having a preexisting wellbore casing 102 by coupling a conventional tubular member 104 defining an internal passage 104a to the threaded portion 12b of the first tubular support member 12 in step 202. In a preferred embodiment, during placement of the assembly 10 within the wellbore 100, fluidic materials 106 within the wellbore 100 below the assembly 10 are conveyed through the assembly 10 and into the passage 104a by the fluid passages 52fa, 52fb, 54a, 48a, 44a, and 14a. In this manner, surge pressures that can be created during placement of the assembly 10 within the wellbore 100 are minimized. In a preferred embodiment, the float valve element 50 is pre-set in an auto-fill configuration to permit the fluidic materials 106 to pass through the conical passage 48a of the valve seat 48.

Referring to Figs. 4a-4c, in step 204, fluidic materials 108 may then be injected into and through the tubular member 104 and assembly 10 to thereby ensure that all of the fluid passages 104a, 14a, 44a, 48a, 54a, 52fa, and 52fb are functioning properly.

Referring to Figs. 5a-5c, in step 206, a bottom plug 110 may then be injected into the fluidic materials 108 and into the assembly 10 and then positioned in the throat passage 44ab of the valve member 44. In this manner, the region of the passage 44a upstream from the plug 110 may be fluidically isolated from the region of the passage 44a downstream from the plug 110. In a preferred embodiment, the proper placement of the plug 110 may be indicated by a corresponding increase in the operating pressure of the fluidic material 108.

Referring to Figs. 6a-6c, in step 208, the sliding sleeve 42 may then be displaced relative to the valve member 44 by displacing the tubular member 104 by applying, for example, a downward force of approximately 5,000 lbf on the

assembly 10. In this manner, the tubular member 104, the first tubular support member 12, the second tubular support member 14, the third tubular support member 16, the expansion cone 18, the annular spacer 22, the fourth tubular support member 24, the fifth tubular support member 26, the sixth tubular support member 38, the collet 40, and the sliding sleeve 42 are displaced in the longitudinal direction relative to the expansion cone launcher 20 and the valve member 44. In this manner, fluidic materials within the passage 44a upstream of the plug 110 may bypass the plug by passing through the first passages, 44da and 44db, through the annular passage 46, and through the second passages, 44ea and 44eb, into the region of the passage 44a downstream from the plug. Furthermore, in this manner, the rupture disc 36 is fluidically isolated from the passages 14a and 44a.

Referring to Figs. 7a-7c, in step 210, a hardenable fluidic sealing material 112 may then be injected into the assembly 10 and conveyed through the passages 104a, 14a, 44a, 44da, 44db, 46, 44ea, 44eb, 48a, 54a, 52fa, and 52fb into the wellbore 100. In this manner, a hardenable fluidic sealing material such as, for example, cement, may be injected into the annular region between the expansion cone launcher 20 and the wellbore 100 in order to subsequently form an annular body of cement around the radially expanded expansion cone launcher 20. Furthermore, in this manner, the radial passage 30a and the rupture disc 36 are not exposed to the hardenable fluidic sealing material 112.

Referring to Figs. 8a-8c, in step 212, upon the completion of the injection of the hardenable fluidic sealing material 112, a nonhardenable fluidic material 114 may be injected into the assembly 10, and a top plug 116 may then be injected into the assembly 10 along with the fluidic materials 114 and then positioned in the throat passage 44aa of the valve member 44. In this manner, the region of the passage 44a upstream from the first passages, 44da and 44db, may be fluidically isolated from the first passages. In a preferred embodiment, the proper placement of the plug 116 may be indicated by a corresponding increase in the operating pressure of the fluidic material 114.

Referring to Fig. 9a-9c, in step 214, the sliding sleeve 42 may then be displaced relative to the valve member 44 by displacing the tubular member 104

by applying, for example, an upward force of approximately 13,000 lbf on the assembly 10. In this manner, the tubular member 104, the first tubular support member 12, the second tubular support member 14, the third tubular support member 16, the expansion cone 18, the annular spacer 22, the fourth tubular support member 24, the fifth tubular support member 26, the sixth tubular support member 38, the collet 40, and the sliding sleeve 42 are displaced in the longitudinal direction relative to the expansion cone launcher 20 and the valve member 44. In this manner, fluidic materials within the passage 44a upstream of the plug 110 may no longer bypass the plug by passing through the first passages, 44da and 44db, through the annular passage 46, and through the second passages, 44ea and 44eb, into the region of the passage 44a downstream from the plug. Furthermore, in this manner, the rupture disc 36 is no longer fluidically isolated from the fluid passages 14a and 44a.

Referring to Figs. 10a-10c, in step 216, the fluidic material 114 may be injected into the assembly 10. The continued injection of the fluidic material 114 may increase the operating pressure within the passages 14a and 44a until the burst disc 36 is opened thereby permitting the pressurized fluidic material 114 to pass through the radial passage 30a and into an annular region 118 defined by the second tubular support member 14, the third tubular support member 16, the sixth tubular support member 38, the collet 40, the sliding sleeve 42, the shoe 54, and the seventh tubular support member 56. The pressurized fluidic material 114 within the annular region 118 directly applies a longitudinal force upon the fifth tubular support member 26 and the sixth tubular support member 38. The longitudinal force in turn is applied to the expansion cone 18. In this manner, the expansion cone 18 is displaced relative to the expansion cone launcher 20 thereby radially expanding and plastically deforming the expansion cone launcher.

In an alternative embodiment of the method 200, the injection and placement of the top plug 116 into the liner hanger assembly 10 in step 212 may be omitted.

In an alternative embodiment of the method 200, in step 202, the assembly 10 is positioned at the bottom of the wellbore 100.

In an alternative embodiment, as illustrated in Figs. 11a-11b, during operation, the assembly 10 may be used to form or repair a wellbore casing by implementing a method 250 in which, as illustrated in Figs. 3a-3c, the assembly 10 may initially be positioned within a wellbore 100 having a preexisting wellbore casing 102 by coupling a conventional tubular member 104 defining an internal passage 104a to the threaded portion 12b of the first tubular support member 12 in step 252. In a preferred embodiment, during placement of the assembly 10 within the wellbore 100, fluidic materials 106 within the wellbore 100 below the assembly 10 are conveyed through the assembly 10 and into the passage 104a by the fluid passages 52fa, 52fb, 54a, 48a, 44a, and 14a. In this manner, surge pressures that can be created during placement of the assembly 10 within the wellbore 100 are minimized. In a preferred embodiment, the float valve element 50 is pre-set in an auto-fill configuration to permit the fluidic materials 106 to pass through the conical passage 48a of the valve seat 48.

Referring to Figs. 4a-4c, in step 254, fluidic materials 108 may then be injected into and through the tubular member 104 and assembly 10 to thereby ensure that all of the fluid passages 104a, 14a, 44a, 48a, 54a, 52fa, and 52fb are functioning properly.

Referring to Figs. 5a-5c, in step 256, the bottom plug 110 may then be injected into the fluidic materials 108 and into the assembly 10 and then positioned in the throat passage 44ab of the valve member 44. In this manner, the region of the passage 44a upstream from the plug 110 may be fluidically isolated from the region of the passage 44a downstream from the plug 110. In a preferred embodiment, the proper placement of the plug 110 may be indicated by a corresponding increase in the operating pressure of the fluidic material 108.

Referring to Figs. 12a-12c, in step 258, a fluidic material 114 may then be injected into the assembly to thereby increase the operating pressure within the passages 14a and 44a until the burst disc 36 is opened thereby permitting the pressurized fluidic material 114 to pass through the radial passage 30a and into an annular region 118 defined by the second tubular support member 14, the third tubular support member 16, the sixth tubular support member 38, the

collet 40, the sliding sleeve 42, the shoe 54, and the seventh tubular support member 56. The pressurized fluidic material 114 within the annular region 118 directly applies a longitudinal force upon the fifth tubular support member 26 and the sixth tubular support member 38. The longitudinal force in turn is applied to the expansion cone 18. In this manner, the expansion cone 18 is displaced relative to the expansion cone launcher 20 thereby disengaging the collet 40 and the sliding sleeve 42 and radially expanding and plastically deforming the expansion cone launcher. In a preferred embodiment, the radial expansion process in step 408 is continued to a location below the overlap between the expansion cone launcher 20 and the preexisting wellbore casing 102.

Referring to Figs. 13a-13c, in step 260, the sliding sleeve 42 may then be displaced relative to the valve member 44 by (1) displacing the expansion cone 18 in a downward direction using the tubular member 104 and (2) applying, using the tubular member 104 a downward force of, for example, approximately 5,000 lbf on the assembly 10. In this manner, the coupling 40b of the collet 40 reengages the external groove 42e of the sliding sleeve 42. Furthermore, in this manner, the tubular member 104, the first tubular support member 12, the second tubular support member 14, the third tubular support member 16, the expansion cone 18, the annular spacer 22, the fourth tubular support member 24, the fifth tubular support member 26, the sixth tubular support member 38, the collet 40, and the sliding sleeve 42 are displaced in the longitudinal direction relative to the expansion cone launcher 20 and the valve member 44. In this manner, fluidic materials within the passage 44a upstream of the plug 110 may bypass the plug by passing through the first passages, 44da and 44db, through the annular passage 46, and through the second passages, 44ea and 44eb, into the region of the passage 44a downstream from the plug. Furthermore, in this manner, the fluid passage 30a is fluidically isolated from the passages 14a and 44a.

Referring to Figs. 14a-14c, in step 262, the hardenable fluidic sealing material 112 may then be injected into the assembly 10 and conveyed through the passages 104a, 14a, 44a, 44da, 44db, 46, 44ea, 44eb, 48a, 54a, 52fa, and 52fb

into the wellbore 100. In this manner, a hardenable fluidic sealing material such as, for example, cement, may be injected into the annular region between the expansion cone launcher 20 and the wellbore 100 in order to subsequently form an annular body of cement around the radially expanded expansion cone launcher 20. Furthermore, in this manner, the radial passage 30a and the rupture disc 36 are not exposed to the hardenable fluidic sealing material 112.

Referring to Figs. 15a-15c, in step 264, upon the completion of the injection of the hardenable fluidic sealing material 112, the nonhardenable fluidic material 114 may be injected into the assembly 10, and the top plug 116 may then be injected into the assembly 10 along with the fluidic materials 114 and then positioned in the throat passage 44aa of the valve member 44. In this manner, the region of the passage 44a upstream from the first passages, 44da and 44db, may be fluidically isolated from the first passages. In a preferred embodiment, the proper placement of the plug 116 may be indicated by a corresponding increase in the operating pressure of the fluidic material 114.

Referring to Figs. 16a-16c, in step 266, the sliding sleeve 42 may then be displaced relative to the valve member 44 by displacing the tubular member 104 by applying, for example, an upward force of approximately 13,000 lbf on the assembly 10. In this manner, the tubular member 104, the first tubular support member 12, the second tubular support member 14, the third tubular support member 16, the expansion cone 18, the annular spacer 22, the fourth tubular support member 24, the fifth tubular support member 26, the sixth tubular support member 38, the collet 40, and the sliding sleeve 42 are displaced in the longitudinal direction relative to the expansion cone launcher 20 and the valve member 44. In this manner, fluidic materials within the passage 44a upstream of the plug 110 may no longer bypass the plug by passing through the first passages, 44da and 44db, through the annular passage 46, and through the second passages, 44ea and 44eb, into the region of the passage 44a downstream from the plug. Furthermore, in this manner, the passage 30a is no longer fluidically isolated from the fluid passages 14a and 44a.

Referring to Figs. 17a-17c, in step 268, the fluidic material 114 may be injected into the assembly 10. The continued injection of the fluidic material

114 may increase the operating pressure within the passages 14a, 30a, and 44a and the annular region 118. The pressurized fluidic material 114 within the annular region 118 directly applies a longitudinal force upon the fifth tubular support member 26 and the sixth tubular support member 38. The longitudinal
5 force in turn is applied to the expansion cone 18. In this manner, the expansion cone 18 is displaced relative to the expansion cone launcher 20 thereby completing the radial expansion of the expansion cone launcher.

In an alternative embodiment of the method 250, the injection and placement of the top plug 116 into the liner hanger assembly 10 in step 264
10 may omitted.

In an alternative embodiment of the method 250, in step 252, the assembly 10 is positioned at the bottom of the wellbore 100.

In an alternative embodiment of the method 250: (1) in step 252, the assembly 10 is positioned proximate a position below a preexisting section of
15 the wellbore casing 102, and (2) in step 258, the expansion cone launcher 20, and any expandable tubulars coupled to the threaded portion 20c of the expansion cone launcher, are radially expanded and plastically deformed until the shoe 54 of the assembly 10 is proximate the bottom of the wellbore 100. In this manner, the radial expansion process using the assembly 10 provides a
20 telescoping of the radially expanded tubulars into the wellbore 100.

In several alternative embodiments, the assembly 10 may be operated to form a wellbore casing by including or excluding the float valve 50.

In several alternative embodiments, the float valve 50 may be operated in an auto-fill configuration in which tabs are positioned between the float valve
25 50 and the valve seat 48. In this manner, fluidic materials within the wellbore 100 may flow into the assembly 10 from below thereby decreasing surge pressures during placement of the assembly 10 within the wellbore 100. Furthermore, pumping fluidic materials through the assembly 10 at rate of about 6 to 8 bbl/min will displace the tabs from the valve seat 48 and thereby
30 allow the float valve 50 to close.

In several alternative embodiments, prior to the placement of any of the plugs, 110 and 116, into the assembly 10, fluidic materials can be circulated through the assembly 10 and into the wellbore 100.

In several alternative embodiments, once the bottom plug 110 has been positioned into the assembly 10, fluidic materials can only be circulated through the assembly 10 and into the wellbore 100 if the sliding sleeve 42 is in the down position.

In several alternative embodiments, once the sliding sleeve 42 is positioned in the down position, the passage 30a and rupture disc 36 are fluidically isolated from pressurized fluids within the assembly 10.

In several alternative embodiments, once the top plug 116 has been positioned into the assembly 10, no fluidic materials can be circulated through the assembly 10 and into the wellbore 100.

In several alternative embodiments, the assembly 10 may be operated to form or repair a wellbore casing, a pipeline, or a structural support.

Referring to Figs. 18, 18a, 18b, and 18c, an alternative embodiment of a liner hanger assembly 300 includes a first tubular support member 312 defining an internal passage 312a that includes a threaded counterbore 312b at one end, and a threaded counterbore 312c at another end. A second tubular support member 314 defining an internal passage 314a includes a first threaded portion 314b at a first end that is coupled to the threaded counterbore 312c of the first tubular support member 312, a stepped flange 314c, a counterbore 314d, a threaded portion 314e, and internal splines 314f at another end. The stepped flange 314c of the second tubular support member 314 further defines radial passages 314g, 314h, 314i, and 314j.

A third tubular support member 316 defining an internal passage 316a for receiving the second tubular support member 314 includes a first flange 316b, a second flange 316c, a first counterbore 316d, a second counterbore 316e having an internally threaded portion 316f, and an internal flange 316g. The second flange 316c further includes radial passages 316h and 316i.

An annular expansion cone 318 defining an internal passage 318a for receiving the second and third tubular support members, 314 and 316, includes

a counterbore 318b at one end, and a counterbore 318c at another end for receiving the flange 316b of the second tubular support member 316. The annular expansion cone 318 further includes an end face 318d that mates with an end face 316j of the flange 316c of the second tubular support member 316, and an exterior surface 318e having a conical shape in order to facilitate the radial expansion of tubular members. A tubular expansion cone launcher 320 is movably coupled to the exterior surface 318e of the expansion cone 318 and includes a first portion 320a having a first wall thickness, a second portion 320b having a second wall thickness, a threaded portion 320c at one end, and a threaded portion 320d at another end. In a preferred embodiment, the second portion 320b of the expansion cone launcher 320 mates with the conical outer surface 318e of the expansion cone 318. In a preferred embodiment, the second wall thickness of the second portion 320b is less than the first wall thickness of the first portion 320a in order to optimize the radial expansion of the expansion cone launcher 320 by the relative axial displacement of the expansion cone 318. In a preferred embodiment, one or more expandable tubulars are coupled to the threaded connection 320c of the expansion cone launcher 320. In this manner, the assembly 300 may be used to radially expand and plastically deform, for example, thousands of feet of expandable tubulars.

20 An annular spacer 322 defining an internal passage 322a for receiving the second tubular support member 314 is received within the counterbore 318b of the expansion cone 318, and is positioned between an end face 312d of the first tubular support member 312 and an end face of the counterbore 318b of the expansion cone 318. A fourth tubular support member 324 defining an internal passage 324a for receiving the second tubular support member 314 includes a flange 324b that is received within the counterbore 316d of the third tubular support member 316. A fifth tubular support member 326 defining an internal passage 326a for receiving the second tubular support member 314 includes an internal flange 326b for mating with the flange 314c of the second tubular support member and a flange 326c for mating with the internal flange 316g of the third tubular support member 316.

An annular sealing member 328, an annular sealing and support member 330, an annular sealing member 332, and an annular sealing and support member 334 are received within the counterbore 314d of the second tubular support member 314. The annular sealing and support member 330 further includes a radial opening 330a for supporting a rupture disc 336 within the radial opening 314g of the second tubular support member 314 and a sealing member 330b for sealing the radial opening 314h of the second tubular support member. The annular sealing and support member 334 further includes sealing members 334a and 334b for sealing the radial openings 314i and 314j, respectively, of the second tubular support member 314. In an exemplary embodiment, the rupture disc 336 opens when the operating pressure within the radial opening 330b is about 1000 to 5000 psi. In this manner, the rupture disc 336 provides a pressure sensitive valve for controlling the flow of fluidic materials through the radial opening 330a. In several alternative embodiments, the assembly 300 includes a plurality of radial passages 330a, each with corresponding rupture discs 336.

A sixth tubular support member 338 defining an internal passage 338a for receiving the second tubular support member 314 includes a threaded portion 338b at one end that is coupled to the threaded portion 316f of the third tubular support member 316 and a flange 338c at another end that is movably coupled to the interior of the expansion cone launcher 320. An annular collet 340 includes a threaded portion 340a that is coupled to the threaded portion 314e of the second tubular support member 314, and a resilient coupling 340b at another end.

An annular sliding sleeve 342 defining an internal passage 342a includes an internal flange 342b, having sealing members 342c and 342d, and an external groove 342e for releasably engaging the coupling 340b of the collet 340 at one end, and an internal flange 342f, having sealing members 342g and 342h, at another end. During operation, the coupling 340b of the collet 340 may engage the external groove 342e of the sliding sleeve 342 and thereby displace the sliding sleeve in the longitudinal direction. Since the coupling 340b of the collet 340 is resilient, the collet 340 may be disengaged or reengaged with the

sliding sleeve 342. An annular valve member 344 defining an internal passage 344a, having a throat 344aa, includes a flange 344b at one end, having external splines 344c for engaging the internal splines 314f of the second tubular support member 314, an interior flange 344d having a first set of radial
5 passages, 344da and 344db, and a counterbore 344e, a second set of radial passages, 344fa and 344fb, and a threaded portion 344g at another end.

An annular valve member 346 defining an internal passage 346a, having a throat 346aa, includes an end portion 346b that is received in the counterbore 344e of the annular valve member 344, a set of radial openings, 346ca and
10 346cb, and a flange 346d at another end. An annular valve member 348 defining an internal passage 348a for receiving the annular valve members 344 and 346 includes a flange 348b having a threaded counterbore 348c at one end for engaging the threaded portion 344g of the annular valve member, a counterbore 348d for mating with the flange 346d of the annular valve member,
15 and a threaded annular recess 348e at another end.

The annular valve members 344, 346, and 348 define an annular passage 350 that fluidically couples the radial passages 344fa, 344fb, 346ca, and 346cb. Furthermore, depending upon the position of the sliding sleeve 342, the fluid passages, 344da and 344db, may be fluidically coupled to the passages 344fa,
20 344fb, 346ca, 346cb, and 350. In this manner, fluidic materials may bypass the portion of the passage 346a between the passages 344da, 344db, 346ca, and 346cb. Furthermore, the sliding sleeve 342 and the valve members 344, 346, and 348 together define a sliding sleeve valve for controllably permitting fluidic materials to bypass the intermediate portion of the passage 346a
25 between the passages, 344da, 344db, 346ca, and 346cb. During operation of the sliding sleeve valve, the flange 348b limits movement of the sliding sleeve 342 in the longitudinal direction.

In a preferred embodiment, the collet 340 includes a set of couplings 340b that engage the external groove 342e of the sliding sleeve 342. During
30 operation, the collet couplings 340b latch over and onto the external groove 342e of the sliding sleeve 342. In a preferred embodiment, a longitudinal force of at least about 10,000 to 13,000 lbf is required to pull the couplings 340b off

of, and out of engagement with, the external groove 342e of the sliding sleeve 342. In an exemplary embodiment, the application of a longitudinal force less than about 10,000 to 13,000 lbf indicates that the collet couplings 340b are latched onto the external shoulder of the sliding sleeve 342, and that the sliding sleeve 342 is in the up or the down position relative to the valve member 344. In a preferred embodiment, the collet 340 includes a conventional internal shoulder that transfers the weight of the first tubular support member 312 and expansion cone 318 onto the sliding sleeve 342. In a preferred embodiment, the collet 340 further includes a conventional set of internal lugs for engaging the splines 344c of the valve member 344.

An annular valve seat 352 defining a conical internal passage 352a for receiving a conventional float valve element 354 includes a threaded annular recess 352b for engaging the threaded portion 348e of the valve member 348, at one end, and an externally threaded portion 352c at another end. In an alternative embodiment, the float valve element 354 is omitted. An annular valve seat mounting element 356 defining an internal passage 356a for receiving the valve seat 352 and float valve 354 includes an internally threaded portion 356b for engaging the externally threaded portion 352c of the valve seat 352, an externally threaded portion 356c, an internal flange 356d, radial passages, 356ea and 356eb, and an end member 356f, having axial passages, 356fa and 356fb.

A shoe 358 defining an internal passage 358a for receiving the valve seat mounting element 356 includes a first threaded annular recess 358b, and a second threaded annular recess 358c for engaging the threaded portion 320d of the expansion cone launcher 320, at one end, a first threaded counterbore 358d for engaging the threaded portion 356c of the of the valve seat mounting element, and a second counterbore 358e for mating with the end member 356f of the mounting element. In a preferred embodiment, the shoe 358 is fabricated from a ceramic and/or a composite material in order to facilitate the subsequent removal of the shoe by drilling.

A seventh tubular support member 360 defining an internal passage 360a for receiving the sliding sleeve 342 and the valve members 344, 346, and

348 is positioned within the expansion cone launcher 320 that includes an internally threaded portion 360b at one end for engaging the externally threaded portion of the annular recess 358b of the shoe 358. In a preferred embodiment, during operation of the assembly, the end of the seventh tubular support member 360 limits the longitudinal movement of the expansion cone 318 in the direction of the shoe 358 by limiting the longitudinal movement of the sixth tubular support member 338. An annular centralizer 362 defining an internal passage 362 for supporting the valve member 348 is positioned within the seventh tubular support member 360 that includes axial passages 362b and 362c.

Referring to Figs. 19a-19b, during operation, the assembly 300 may be used to form or repair a wellbore casing by implementing a method 400 in which, as illustrated in Figs. 20a-20c, the assembly 300 may initially be positioned within a wellbore 1000 having a preexisting wellbore casing 1002 by coupling a conventional tubular member 1004 defining an internal passage 1004a to the threaded portion 312b of the first tubular support member 312 in step 402. In a preferred embodiment, during placement of the assembly 300 within the wellbore 1000, fluidic materials 1006 within the wellbore 1000 below the assembly 300 are conveyed through the assembly 300 and into the passage 1004a by the fluid passages 356fa, 356fb, 352a, 348a, 346a, 344a, and 314a. In this manner, surge pressures that can be created during placement of the assembly 300 within the wellbore 1000 are minimized. In a preferred embodiment, the float valve element 354 is pre-set in an auto-fill configuration to permit the fluidic materials 1006 to pass through the conical passage 352a of the valve seat 352.

Referring to Figs. 21a-21c, in step 404, fluidic materials 1008 may then be injected into and through the tubular member 1004 and assembly 300 to thereby ensure that all of the fluid passages 1004a, 314a, 344a, 346a, 348a, 352a, 356fa, and 356fb are functioning properly.

Referring to Figs. 22a-22c, in step 406, a bottom plug 1010 may then be injected into the fluidic materials 1008 and into the assembly 300 and then positioned in the throat passage 346aa of the valve member 346. In this

manner, the region of the passage 346a upstream from the plug 1010 may be fluidically isolated from the region of the passage 346a downstream from the plug 1010. In a preferred embodiment, the proper placement of the plug 1010 may be indicated by a corresponding increase in the operating pressure of the fluidic material 1008.

Referring to Figs. 23a-23c, in step 408, the sliding sleeve 342 may then be displaced relative to the valve member 344 by displacing the tubular member 1004 by applying, for example, a downward force of approximately 5,000 lbf on the assembly 300. In this manner, the tubular member 1004, the first tubular support member 312, the second tubular support member 314, the third tubular support member 316, the expansion cone 318, the annular spacer 322, the fourth tubular support member 324, the fifth tubular support member 326, the sixth tubular support member 338, the collet 340, and the sliding sleeve 342 are displaced in the longitudinal direction relative to the expansion cone launcher 320 and the valve member 344. In this manner, fluidic materials within the passage 344a upstream of the plug 1010 may bypass the plug by passing through the first passages, 344da and 344db, through the annular passage 342a, through the second passages, 344fa and 344fb, through the annular passage 350, through the passages, 346ca and 346cb, into the region of the passage 348a downstream from the plug. Furthermore, in this manner, the rupture disc 336 is fluidically isolated from the passages 314a and 344a.

Referring to Figs. 24a-24c, in step 410, a hardenable fluidic sealing material 1012 may then be injected into the assembly 300 and conveyed through the passages 1004a, 314a, 344a, 344da, 344db, 342a, 344fa, 344fb, 350, 346ca, 346cb, 348a, 352a, 356fa, and 356fb into the wellbore 1000. In this manner, a hardenable fluidic sealing material such as, for example, cement, may be injected into the annular region between the expansion cone launcher 320 and the wellbore 1000 in order to subsequently form an annular body of cement around the radially expanded expansion cone launcher 320. Furthermore, in this manner, the radial passage 330a and the rupture disc 336 are not exposed to the hardenable fluidic sealing material 1012.

Referring to Figs. 25a-25c, in step 412, upon the completion of the injection of the hardenable fluidic sealing material 1012, a nonhardenable fluidic material 1014 may be injected into the assembly 300, and a top plug 1016 may then be injected into the assembly 300 along with the fluidic materials 1014 and then positioned in the throat passage 344aa of the valve member 344. In this manner, the region of the passage 344a upstream from the top plug 1016 may be fluidically isolated from region downstream from the top plug. In a preferred embodiment, the proper placement of the plug 1016 may be indicated by a corresponding increase in the operating pressure of the fluidic material 1014.

Referring to Fig. 26a-26c, in step 414, the sliding sleeve 42 may then be displaced relative to the valve member 344 by displacing the tubular member 1004 by applying, for example, an upward force of approximately 13,000 lbf on the assembly 300. In this manner, the tubular member 1004, the first tubular support member 312, the second tubular support member 314, the third tubular support member 316, the expansion cone 318, the annular spacer 322, the fourth tubular support member 324, the fifth tubular support member 326, the sixth tubular support member 338, the collet 340, and the sliding sleeve 342 are displaced in the longitudinal direction relative to the expansion cone launcher 320 and the valve member 344. In this manner, fluidic materials within the passage 344a upstream of the bottom plug 1010 may no longer bypass the bottom plug by passing through the first passages, 344da and 344db, through the annular passage 342a, through the second passages, 344fa and 344fb, through the annular passage 350, and through the passages, 346ca and 346cb, into region of the passage 348a downstream from the bottom plug. Furthermore, in this manner, the rupture disc 336 is no longer fluidically isolated from the fluid passages 314a and 344a.

Referring to Figs. 27a-27c, in step 416, the fluidic material 1014 may be injected into the assembly 300. The continued injection of the fluidic material 1014 may increase the operating pressure within the passages 314a and 344a until the burst disc 336 is opened thereby permitting the pressurized fluidic material 1014 to pass through the radial passage 330a and into an annular

region 1018 defined by the second tubular support member 314, the third
tubular support member 316, the sixth tubular support member 338, the collet
340, the sliding sleeve 342, the valve members, 344 and 348, the shoe 358, and
the seventh tubular support member 360. The pressurized fluidic material
5 1014 within the annular region 1018 directly applies a longitudinal force upon
the fifth tubular support member 326 and the sixth tubular support member
338. The longitudinal force in turn is applied to the expansion cone 318. In
this manner, the expansion cone 318 is displaced relative to the expansion cone
launcher 320 thereby radially expanding and plastically deforming the
10 expansion cone launcher.

In an alternative embodiment of the method 400, the injection and
placement of the top plug 1016 into the liner hanger assembly 300 in step 412
may omitted.

In an alternative embodiment of the method 400, in step 402, the
15 assembly 300 is positioned at the bottom of the wellbore 1000.

In an alternative embodiment, as illustrated in Figs. 28a-28b, during
operation, the assembly 300 may be used to form or repair a wellbore casing by
implementing a method 450 in which, as illustrated in Figs. 20a-20c, the
assembly 300 may initially be positioned within a wellbore 1000 having a
20 preexisting wellbore casing 1002 by coupling a conventional tubular member
1004 defining an internal passage 1004a to the threaded portion 312b of the
first tubular support member 312 in step 452. In a preferred embodiment,
during placement of the assembly 300 within the wellbore 1000, fluidic
materials 1006 within the wellbore 1000 below the assembly 300 are conveyed
25 through the assembly 300 and into the passage 1004a by the fluid passages
356fa, 356fb, 352a, 348a, 346a, 344a, and 314a. In this manner, surge pressures
that can be created during placement of the assembly 300 within the wellbore
1000 are minimized. In a preferred embodiment, the float valve element 354 is
pre-set in an auto-fill configuration to permit the fluidic materials 1006 to pass
30 through the conical passage 352a of the valve seat 352.

Referring to Figs. 21a-21c, in step 454, in step 454, fluidic materials 1008
may then be injected into and through the tubular member 1004 and assembly

300 to thereby ensure that all of the fluid passages 1004a, 314a, 344a, 346a, 348a, 352a, 356fa, and 356fb are functioning properly.

Referring to Figs. 22a-22c, in step 456, the bottom plug 1010 may then be injected into the fluidic materials 1008 and into the assembly 300 and then positioned in the throat passage 346aa of the valve member 346. In this manner, the region of the passage 346a upstream from the plug 1010 may be fluidically isolated from the region of the passage 346a downstream from the plug 1010. In a preferred embodiment, the proper placement of the plug 1010 may be indicated by a corresponding increase in the operating pressure of the fluidic material 1008.

Referring to Figs. 29a-29c, in step 458, the fluidic material 1014 may then be injected into the assembly 300 to thereby increase the operating pressure within the passages 314a and 344a until the burst disc 336 is opened thereby permitting the pressurized fluidic material 1014 to pass through the radial passage 330a and into an annular region 1018 defined by the defined by the second tubular support member 314, the third tubular support member 316, the sixth tubular support member 338, the collet 340, the sliding sleeve 342, the valve members, 344 and 348, the shoe 358, and the seventh tubular support member 360. The pressurized fluidic material 1014 within the annular region 1018 directly applies a longitudinal force upon the fifth tubular support member 326 and the sixth tubular support member 338. The longitudinal force in turn is applied to the expansion cone 318. In this manner, the expansion cone 318 is displaced relative to the expansion cone launcher 320 thereby disengaging the collet 340 and the sliding sleeve 342 and radially expanding and plastically deforming the expansion cone launcher. In a preferred embodiment, the radial expansion process in step 458 is continued to a location below the overlap between the expansion cone launcher 320 and the preexisting wellbore casing 1002.

Referring to Figs. 30a-30c, in step 460, the sliding sleeve 342 may then be displaced relative to the valve member 344 by (1) displacing the expansion cone 318 in a downward direction using the tubular member 1004 and (2) applying, using the tubular member 1004 a downward force of, for example,

approximately 5,000 lbf on the assembly 300. In this manner, the coupling 340b of the collet 340 reengages the external groove 342e of the sliding sleeve 342. Furthermore, in this manner, the tubular member 1004, the first tubular support member 312, the second tubular support member 314, the third 5 tubular support member 316, the expansion cone 318, the annular spacer 322, the fourth tubular support member 324, the fifth tubular support member 326, the sixth tubular support member 338, the collet 340, and the sliding sleeve 342 are displaced in the longitudinal direction relative to the expansion cone launcher 320 and the valve member 344. In this manner, fluidic materials 10 within the passage 344a upstream of the bottom plug 1010 may bypass the plug by passing through the passages, 344da and 344db, the annular passage 342a, the passages, 344fa and 344fb, the annular passage 350, and the passages, 346ca and 346cb, into the passage 348a downstream from the plug. Furthermore, in this manner, the fluid passage 330a is fluidically isolated from 15 the passages 314a and 344a.

Referring to Figs. 31a-31c, in step 462, the hardenable fluidic sealing material 1012 may then be injected into the assembly 300 and conveyed through the passages 1004a, 314a, 344a, 344da, 344db, 342, 344fa, 344fb, 350, 346ca, 346cb, 348a, 352b, 356fa, and 356fb into the wellbore 1000. In this 20 manner, a hardenable fluidic sealing material such as, for example, cement, may be injected into the annular region between the expansion cone launcher 320 and the wellbore 1000 in order to subsequently form an annular body of cement around the radially expanded expansion cone launcher 320. Furthermore, in this manner, the radial passage 330a and the rupture disc 336 25 are not exposed to the hardenable fluidic sealing material 1012.

Referring to Figs. 32a-32c, in step 464, upon the completion of the injection of the hardenable fluidic sealing material 1012, the nonhardenable fluidic material 1014 may be injected into the assembly 300, and the top plug 1016 may then be injected into the assembly 300 along with the fluidic 30 materials 1014 and then positioned in the throat passage 344aa of the valve member 344. In this manner, the region of the passage 344a upstream from the top plug 1016 may be fluidically isolated from the region within the passage

downstream from the top plug. In a preferred embodiment, the proper placement of the plug 1016 may be indicated by a corresponding increase in the operating pressure of the fluidic material 1014.

Referring to Figs. 33a-33c, in step 466, the sliding sleeve 342 may then be displaced relative to the valve member 344 by displacing the tubular member 1004 by applying, for example, an upward force of approximately 13,000 lbf on the assembly 300. In this manner, the tubular member 1004, the first tubular support member 312, the second tubular support member 314, the third tubular support member 316, the expansion cone 318, the annular spacer 322, the fourth tubular support member 324, the fifth tubular support member 326, the sixth tubular support member 338, the collet 340, and the sliding sleeve 342 are displaced in the longitudinal direction relative to the expansion cone launcher 320 and the valve member 344. In this manner, fluidic materials within the passage 344a upstream of the bottom plug 110 may no longer bypass the plug by passing through the passages, 344da and 344db, the annular passage 342a, the passages, 344fa and 344fb, the annular passage 350, and the passages, 346ca and 346cb, into the passage 348a downstream from the plug. Furthermore, in this manner, the passage 330a is no longer fluidically isolated from the fluid passages 314a and 344a.

Referring to Figs. 34a-34c, in step 468, the fluidic material 1014 may be injected into the assembly 300. The continued injection of the fluidic material 1014 may increase the operating pressure within the passages 314a, 330a, and 344a and the annular region 1018. The pressurized fluidic material 1014 within the annular region 1018 directly applies a longitudinal force upon the fifth tubular support member 326 and the sixth tubular support member 338. The longitudinal force in turn is applied to the expansion cone 318. In this manner, the expansion cone 318 is displaced relative to the expansion cone launcher 320 thereby completing the radial expansion of the expansion cone launcher.

In an alternative embodiment of the method 450, the injection and placement of the top plug 1016 into the liner hanger assembly 300 in step 464 may be omitted.

In an alternative embodiment of the method 450, in step 452, the assembly 300 is positioned at the bottom of the wellbore 1000.

In an alternative embodiment of the method 450: (1) in step 452, the assembly 300 is positioned proximate a position below a preexisting section of the wellbore casing 1002, and (2) in step 458, the expansion cone launcher 320, and any expandable tubulars coupled to the threaded portion 320c of the expansion cone launcher, are radially expanded and plastically deformed until the shoe 358 of the assembly 300 is proximate the bottom of the wellbore 1000. In this manner, the radial expansion process using the assembly 300 provides a telescoping of the radially expanded tubulars into the wellbore 1000.

In several alternative embodiments, the assembly 300 may be operated to form a wellbore casing by including or excluding the float valve 354.

In several alternative embodiments, the float valve 354 may be operated in an auto-fill configuration in which tabs are positioned between the float valve 354 and the valve seat 352. In this manner, fluidic materials within the wellbore 1000 may flow into the assembly 300 from below thereby decreasing surge pressures during placement of the assembly 300 within the wellbore 1000. Furthermore, pumping fluidic materials through the assembly 300 at rate of about 6 to 8 bbl/min will displace the tabs from the valve seat 352 and thereby allow the float valve 354 to close.

In several alternative embodiments, prior to the placement of any of the plugs, 1010 and 1016, into the assembly 300, fluidic materials can be circulated through the assembly 300 and into the wellbore 1000.

In several alternative embodiments, once the bottom plug 1010 has been positioned into the assembly 300, fluidic materials can only be circulated through the assembly 300 and into the wellbore 1000 if the sliding sleeve 342 is in the down position.

In several alternative embodiments, once the sliding sleeve 342 is positioned in the down position, the passage 330a and rupture disc 336 are fluidically isolated from pressurized fluids within the assembly 300.

In several alternative embodiments, once the top plug 1016 has been positioned into the assembly 300, no fluidic materials can be circulated through the assembly 300 and into the wellbore 1000.

In several alternative embodiments, the assembly 300 may be operated to
5 form or repair a wellbore casing, a pipeline, or a structural support.

In a preferred embodiment, the design and operation of the liner hanger assemblies 10 and 300 are provided substantially as described and illustrated in Appendix A to the present application.

In a preferred embodiment, the design and operation of the liner hanger
10 assemblies 10 and 300 are provided substantially as described in one or more of the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on
15 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no.
20 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) U.S. patent application serial no. _____, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial
25 no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no.
30 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. _____, attorney docket no.

25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. _____, attorney docket no. 25791.45, filed on 7/28/2000, and (19) U.S. provisional patent application serial
5 no. _____, attorney docket no. 25791.46, filed on 7/28/2000, the disclosures of which are incorporated herein by reference.

A method of forming a wellbore casing within a borehole within a subterranean formation has been described that includes positioning an expandable tubular member within the borehole, injecting fluidic materials into
10 the expandable tubular member, fluidically isolating a first region from a second region within the expandable tubular member, fluidically coupling the first and second regions, injecting a hardenable fluidic sealing material into the expandable tubular member, fluidically decoupling the first and second regions and injecting a non-hardenable fluidic material into the expandable tubular
15 member to radially expand the tubular member. In an exemplary embodiment, positioning the expandable tubular member within the borehole includes positioning an end of the expandable tubular member adjacent to the bottom of the borehole. In an exemplary embodiment, the method further includes fluidically isolating the second region from a third region within the expandable
20 tubular member.

An apparatus for forming a wellbore casing within a borehole within a subterranean formation has also been described that includes means for positioning an expandable tubular member within the borehole, means for injecting fluidic materials into the expandable tubular member, means for
25 fluidically isolating a first region from a second region within the expandable tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable
30 tubular member to radially expand the tubular member. In an exemplary embodiment, the means for positioning the expandable tubular member within the borehole includes means for positioning an end of the expandable tubular

member adjacent to the bottom of the borehole. In an exemplary embodiment, the apparatus further includes means for fluidically isolating the second region from a third region within the expandable tubular member.

A method of forming a wellbore casing within a borehole within a subterranean formation has also been described that includes positioning an expandable tubular member within the borehole, injecting fluidic materials into the expandable tubular member, fluidically isolating a first region from a second region within the expandable tubular member, injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member, fluidically coupling the first and second regions, injecting a hardenable fluidic sealing material into the expandable tubular member, fluidically decoupling the first and second regions, and injecting a non-hardenable fluidic material into the expandable tubular member to radially expand another portion of the tubular member. In an exemplary embodiment, positioning the expandable tubular member within the borehole includes positioning an end of the expandable tubular member adjacent to the bottom of the borehole. In an exemplary embodiment, positioning the expandable tubular member within the borehole includes positioning an end of the expandable tubular member adjacent to a preexisting section of wellbore casing within the borehole. In an exemplary embodiment, injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member includes injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member until an end portion of the tubular member is positioned proximate the bottom of the borehole. In an exemplary embodiment, the method further includes fluidically isolating the second region from a third region within the expandable tubular member.

An apparatus for forming a wellbore casing within a borehole within a subterranean formation has also been described that includes means for positioning an expandable tubular member within the borehole, means for injecting fluidic materials into the expandable tubular member, means for fluidically isolating a first region from a second region within the expandable

tubular member, means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand another portion of the tubular member. In an exemplary embodiment, the means for positioning the expandable tubular member within the borehole includes means for positioning an end of the expandable tubular member adjacent to the bottom of the borehole. In an exemplary embodiment, the means for positioning the expandable tubular member within the borehole includes means for positioning an end of the expandable tubular member adjacent to a preexisting section of wellbore casing within the borehole. In an exemplary embodiment, the means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member includes means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member until an end portion of the tubular member is positioned proximate the bottom of the borehole. In an exemplary embodiment, the apparatus further includes means for fluidically isolating the second region from a third region within the expandable tubular member.

An apparatus for forming a wellbore casing within a borehole within a subterranean formation has also been described that includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having first and second throat passages, defining second and third radial passages fluidically

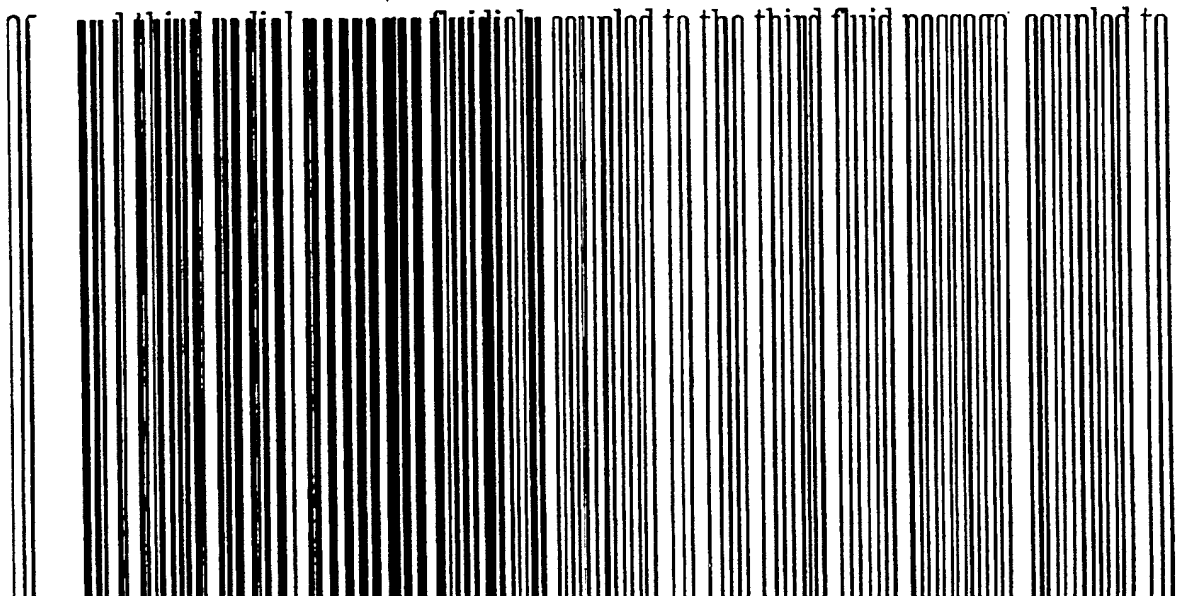
coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling
5 the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve.

An apparatus for forming a wellbore casing in a borehole in a
10 subterranean formation has also been described that includes means for radially expanding an expandable tubular member, and means for injecting a hardenable fluidic sealing material into an annulus between the expandable tubular member and the borehole. In an exemplary embodiment, the means for injecting a hardenable fluidic sealing material into an annulus between the
15 expandable tubular member and the borehole includes a sliding sleeve valve.

A method of operating an apparatus for forming a wellbore casing within a borehole within a subterranean formation has also been described in which the apparatus includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves
20 fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and
25 second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for
30 controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular

valve member, and the annular sleeve. The method includes positioning the apparatus within the borehole, injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand the expandable tubular member. In an exemplary embodiment, positioning the apparatus within the borehole includes positioning an end of the expandable tubular member adjacent to the bottom of the borehole. In an exemplary embodiment, the method further includes positioning a top plug in the top throat passage.

A method of operating an apparatus for forming a wellbore casing within a borehole within a subterranean formation has also been described in which the apparatus includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second



apparatus within the borehole, injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, injecting a non-hardenable fluidic material through the first fluid passages and the first radial passages and pressure sensitive valves into the

5 annular region to radially expand a portion of the expandable tubular member, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial

10 passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand another portion of the expandable tubular member. In an exemplary embodiment, positioning the apparatus within the borehole includes positioning an end of the expandable tubular member

15 adjacent to the bottom of the borehole. In an exemplary embodiment, positioning the apparatus within the borehole includes positioning an end of the expandable tubular member adjacent to a preexisting section of wellbore casing within the borehole. In an exemplary embodiment, injecting a non-hardenable fluidic material into the first fluid passage and first radial passages and

20 pressure sensitive valves to radially expand a portion of the expandable tubular member includes injecting a non-hardenable fluidic material into the first fluid passage and first radial passages and pressure sensitive valves to radially expand the expandable tubular member until an end portion of the tubular member is positioned proximate the bottom of the borehole. In an exemplary

25 embodiment, the method further includes positioning a top plug in the top throat passage.

A method of coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described that includes positioning an expandable tubular

30 member within the preexisting structure, injecting fluidic materials into the expandable tubular member, fluidically isolating a first region from a second region within the expandable tubular member, fluidically coupling the first and

second regions, injecting a hardenable fluidic sealing material into the expandable tubular member, fluidically decoupling the first and second regions and injecting a non-hardenable fluidic material into the expandable tubular member to radially expand the tubular member. In an exemplary embodiment, positioning the expandable tubular member within the preexisting structure includes positioning an end of the expandable tubular member adjacent to the bottom of the preexisting structure. In an exemplary embodiment, the method further includes fluidically isolating the second region from a third region within the expandable tubular member.

10 An apparatus for coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described that includes means for positioning the expandable tubular member within the preexisting structure, means for injecting fluidic materials into the expandable tubular member, means for fluidically isolating a first region from a second region within the expandable tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand the tubular member. In an exemplary embodiment, the means for positioning the expandable tubular member within the preexisting structure includes means for positioning an end of the expandable tubular member adjacent to the bottom of the preexisting structure. In an exemplary embodiment, the apparatus further includes means for fluidically isolating the second region from a third region within the expandable tubular member.

A method of coupling an expandable tubular member to a preexisting structure has also been described that includes positioning the expandable tubular member within the preexisting structure, injecting fluidic materials into the expandable tubular member, fluidically isolating a first region from a second region within the expandable tubular member, injecting a non-hardenable fluidic material into the expandable tubular member to radially

expand at least a portion of the tubular member, fluidically coupling the first and second regions, injecting a hardenable fluidic sealing material into the expandable tubular member, fluidically decoupling the first and second regions, and injecting a non-hardenable fluidic material into the expandable tubular member to radially expand another portion of the tubular member. In an exemplary embodiment, positioning the expandable tubular member within the preexisting structure includes positioning an end of the expandable tubular member adjacent to the bottom of the preexisting structure. In an exemplary embodiment, positioning the expandable tubular member within the preexisting structure includes positioning an end of the expandable tubular member adjacent to a preexisting section of a structural element within the preexisting structure. In an exemplary embodiment, injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member includes injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member until an end portion of the tubular member is positioned proximate the bottom of the preexisting structure. In an exemplary embodiment, the method further includes fluidically isolating the second region from a third region within the expandable tubular member.

An apparatus for coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described that includes means for positioning the expandable tubular member within the preexisting structure, means for injecting fluidic materials into the expandable tubular member, means for fluidically isolating a first region from a second region within the expandable tubular member, means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member, means for fluidically coupling the first and second regions, means for injecting a hardenable fluidic sealing material into the expandable tubular member, means for fluidically decoupling the first and second regions, and means for injecting a non-hardenable fluidic material into the expandable tubular

member to radially expand another portion of the tubular member. In an exemplary embodiment, the means for positioning the expandable tubular member within the preexisting structure includes means for positioning an end of the expandable tubular member adjacent to the bottom of the preexisting structure. In an exemplary embodiment, the means for positioning the expandable tubular member within the preexisting structure includes means for positioning an end of the expandable tubular member adjacent to a preexisting structural element within the preexisting structure. In an exemplary embodiment, the means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member includes means for injecting a non-hardenable fluidic material into the expandable tubular member to radially expand at least a portion of the tubular member until an end portion of the tubular member is positioned proximate the bottom of the preexisting structure. In an exemplary embodiment, the apparatus further includes means for fluidically isolating the second region from a third region within the expandable tubular member.

An apparatus for coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described that includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having first and second throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the

region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve.

An apparatus for coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described that includes means for radially expanding an expandable tubular member, and means for injecting a hardenable fluidic sealing material into an annulus between the expandable tubular member and the borehole. In an exemplary embodiment, the means for injecting a hardenable fluidic sealing material into an annulus between the expandable tubular member and the borehole includes a sliding sleeve valve.

A method of operating an apparatus for coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described in which the apparatus includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve. The method includes positioning the apparatus within the preexisting structure, injecting fluidic materials into the first, second and third fluid passages, positioning a bottom plug in the bottom

throat passage, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand the expandable tubular member. In an exemplary embodiment, positioning the apparatus within the preexisting structure includes positioning an end of the expandable tubular member adjacent to the bottom of the preexisting structure. In an exemplary embodiment, the method further includes positioning a top plug in the top throat passage.

A method of operating an apparatus for coupling an expandable tubular member to a preexisting structure such as, for example, a wellbore casing, a pipeline, or a structural support has also been described in which the apparatus includes a first annular support member defining a first fluid passage and one or more first radial passages having pressure sensitive valves fluidically coupled to the first fluid passage, an annular expansion cone coupled to the first annular support member, an expandable tubular member movably coupled to the expansion cone, a second annular support member defining a second fluid passage coupled to the expandable tubular member, an annular valve member defining a third fluid passage fluidically coupled to the first and second fluid passages having top and bottom throat passages, defining second and third radial passages fluidically coupled to the third fluid passage, coupled to the second annular support member, and movably coupled to the first annular support member, and an annular sleeve releasably coupled to the first annular support member and movably coupled to the annular valve member for controllably fluidically coupling the second and third radial passages. An annular region is defined by the region between the tubular member and the first annular support member, the second annular support member, the annular valve member, and the annular sleeve. The method includes positioning the apparatus within the preexisting structure, injecting fluidic materials into the

first, second and third fluid passages, positioning a bottom plug in the bottom throat passage, injecting a non-hardenable fluidic material through the first fluid passages and the first radial passages and pressure sensitive valves into the annular region to radially expand a portion of the expandable tubular member, displacing the annular sleeve to fluidically couple the second and third radial passages, injecting a hardenable fluidic sealing material through the first, second, and third fluid passages, and the second and third radial passages, displacing the annular sleeve to fluidically decouple the second and third radial passages, and injecting a non-hardenable fluidic material through the first fluid passage and the first radial passages and pressure sensitive valves into the annular region to radially expand another portion of the expandable tubular member. In an exemplary embodiment, positioning the apparatus within the preexisting structure includes positioning an end of the expandable tubular member adjacent to the bottom of the preexisting structure. In an exemplary embodiment, positioning the apparatus within the preexisting structure includes positioning an end of the expandable tubular member adjacent to a preexisting section of a structural element casing within the preexisting structure. In an exemplary embodiment, injecting a non-hardenable fluidic material into the first fluid passage and first radial passages and pressure sensitive valves to radially expand a portion of the expandable tubular member includes injecting a non-hardenable fluidic material into the first fluid passage and first radial passages and pressure sensitive valves to radially expand the expandable tubular member until an end portion of the tubular member is positioned proximate the bottom of the preexisting structure. In an exemplary embodiment, the method further includes positioning a top plug in the top throat passage.

Although this detailed description has shown and described illustrative embodiments of the invention, this description contemplates a wide range of modifications, changes, and substitutions. In some instances, one may employ some features of the present invention without a corresponding use of the other features. Accordingly, it is appropriate that readers should construe the

appended claims broadly, and in a manner consistent with the scope of the invention.

Claims

What is claimed is:

1 1. A method of forming a wellbore casing within a borehole within a
2 subterranean formation, comprising:
3 positioning an expandable tubular member within the borehole;
4 injecting fluidic materials into the expandable tubular member;
5 fluidically isolating a first region from a second region within the
6 expandable tubular member;
7 fluidically coupling the first and second regions;
8 injecting a hardenable fluidic sealing material into the expandable
9 tubular member;
10 fluidically decoupling the first and second regions; and
11 injecting a non-hardenable fluidic material into the expandable tubular
12 member to radially expand the tubular member.

1 2. The method of claim 1, wherein positioning the expandable tubular
2 member within the borehole comprises:
3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the borehole.

1 3. The method of claim 1, further comprising:
2 fluidically isolating the second region from a third region within the
3 expandable tubular member.

1 4. An apparatus for forming a wellbore casing within a borehole within a
2 subterranean formation, comprising:
3 means for positioning an expandable tubular member within the
4 borehole;
5 means for injecting fluidic materials into the expandable tubular
6 member;
7 means for fluidically isolating a first region from a second region within
8 the expandable tubular member;

9 means for fluidically coupling the first and second regions;
10 means for injecting a hardenable fluidic sealing material into the
11 expandable tubular member;
12 means for fluidically decoupling the first and second regions; and
13 means for injecting a non-hardenable fluidic material into the
14 expandable tubular member to radially expand the tubular
15 member.

1 5. The apparatus of claim 4, wherein the means for positioning the
2 expandable tubular member within the borehole comprises:
3 means for positioning an end of the expandable tubular member adjacent
4 to the bottom of the borehole.

1 6. The apparatus of claim 4, further comprising:
2 means for fluidically isolating the second region from a third region within
3 the expandable tubular member.

1 7. A method of forming a wellbore casing within a borehole within a
2 subterranean formation, comprising:
3 positioning an expandable tubular member within the borehole;
4 injecting fluidic materials into the expandable tubular member;
5 fluidically isolating a first region from a second region within the
6 expandable tubular member;
7 injecting a non-hardenable fluidic material into the expandable tubular
8 member to radially expand at least a portion of the tubular
9 member;
10 fluidically coupling the first and second regions;
11 injecting a hardenable fluidic sealing material into the expandable
12 tubular member;
13 fluidically decoupling the first and second regions; and

14 injecting a non-hardenable fluidic material into the expandable tubular
15 member to radially expand another portion of the tubular
16 member.

1 8. The method of claim 7, wherein positioning the expandable tubular
2 member within the borehole comprises:
3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the borehole.

1 9. The method of claim 7, wherein positioning the expandable tubular
2 member within the borehole comprises:
3 positioning an end of the expandable tubular member adjacent to a
4 preexisting section of wellbore casing within the borehole.

1 10. The method of claim 7, wherein injecting a non-hardenable fluidic
2 material into the expandable tubular member to radially expand at least a
3 portion of the tubular member comprises:
4 injecting a non-hardenable fluidic material into the expandable tubular
5 member to radially expand at least a portion of the tubular
6 member until an end portion of the tubular member is positioned
7 proximate the bottom of the borehole.

1 11. The method of claim 7, further comprising:
2 fluidically isolating the second region from a third region within the
3 expandable tubular member.

1 12. An apparatus for forming a wellbore casing within a borehole within a
2 subterranean formation, comprising:
3 means for positioning an expandable tubular member within the
4 borehole;
5 means for injecting fluidic materials into the expandable tubular
6 member;

7 means for fluidically isolating a first region from a second region within
8 the expandable tubular member;
9 means for injecting a non-hardenable fluidic material into the
10 expandable tubular member to radially expand at least a portion of
11 the tubular member;
12 means for fluidically coupling the first and second regions;
13 means for injecting a hardenable fluidic sealing material into the
14 expandable tubular member;
15 means for fluidically decoupling the first and second regions; and
16 means for injecting a non-hardenable fluidic material into the
17 expandable tubular member to radially expand another portion of
18 the tubular member.

1 13. The apparatus of claim 12, wherein means for positioning the expandable
2 tubular member within the borehole comprises:

3 means for positioning an end of the expandable tubular member adjacent
4 to the bottom of the borehole.

1 14. The apparatus of claim 12, wherein means for positioning the expandable
2 tubular member within the borehole comprises:

3 means for positioning an end of the expandable tubular member adjacent
4 to a preexisting section of wellbore casing within the borehole.

1 15. The apparatus of claim 12, wherein means for injecting a non-hardenable
2 fluidic material into the expandable tubular member to radially expand at least
3 a portion of the tubular member comprises:

4 means for injecting a non-hardenable fluidic material into the
5 expandable tubular member to radially expand at least a portion of
6 the tubular member until an end portion of the tubular member is
7 positioned proximate the bottom of the borehole.

1 16. The apparatus of claim 12, further comprising:

- 2 means for fluidically isolating the second region from a third region within
- 3 the expandable tubular member.

1 17. An apparatus for forming a wellbore casing within a borehole within a
2 subterranean formation, comprising:
3 a first annular support member defining a first fluid passage and one or
4 more first radial passages having pressure sensitive valves fluidically
5 coupled to the first fluid passage;
6 an annular expansion cone coupled to the first annular support member;
7 an expandable tubular member movably coupled to the expansion cone;
8 a second annular support member defining a second fluid passage
9 coupled to the expandable tubular member;
10 an annular valve member defining a third fluid passage fluidically coupled
11 to the first and second fluid passages having first and second
12 throat passages, defining second and third radial passages fluidically
13 coupled to the third fluid passage, coupled to the second annular
14 support member, and movably coupled to the first annular support
15 member; and
16 an annular sleeve releasably coupled to the first annular support member
17 and movably coupled to the annular valve member for controllably
18 fluidically coupling the second and third radial passages; and
19 wherein an annular region is defined by the region between the tubular
20 member and the first annular support member, the second
21 annular support member, the annular valve member, and the
22 annular sleeve.

1 18. An apparatus for forming a wellbore casing in a borehole in a
2 subterranean formation, comprising:
3 means for radially expanding an expandable tubular member; and
4 means for injecting a hardenable fluidic sealing material into an annulus
5 between the expandable tubular member and the borehole.

1 19. The apparatus of claim 18, wherein the means for injecting a hardenable
2 fluidic sealing material into an annulus between the expandable tubular
3 member and the borehole, comprises:

4 a sliding sleeve valve.

1 20. A method of operating an apparatus for forming a wellbore casing within
2 a borehole within a subterranean formation, the apparatus comprising:
3 a first annular support member defining a first fluid passage and one or
4 more first radial passages having pressure sensitive valves fluidically
5 coupled to the first fluid passage;
6 an annular expansion cone coupled to the first annular support member;
7 an expandable tubular member movably coupled to the expansion cone;
8 a second annular support member defining a second fluid passage
9 coupled to the expandable tubular member;
10 an annular valve member defining a third fluid passage fluidically coupled
11 to the first and second fluid passages having top and bottom
12 throat passages, defining second and third radial passages fluidically
13 coupled to the third fluid passage, coupled to the second annular
14 support member, and movably coupled to the first annular support
15 member; and
16 an annular sleeve releasably coupled to the first annular support member
17 and movably coupled to the annular valve member for controllably
18 fluidically coupling the second and third radial passages; and
19 wherein an annular region is defined by the region between the tubular
20 member and the first annular support member, the second
21 annular support member, the annular valve member, and the
22 annular sleeve;
23 the method comprising:
24 positioning the apparatus within the borehole;
25 injecting fluidic materials into the first, second and third fluid
26 passages;
27 positioning a bottom plug in the bottom throat passage;
28 displacing the annular sleeve to fluidically couple the second and
29 third radial passages;

30 injecting a hardenable fluidic sealing material through the first,
31 second, and third fluid passages, and the second and third
32 radial passages;
33 displacing the annular sleeve to fluidically decouple the second and
34 third radial passages; and
35 injecting a non-hardenable fluidic material through the first fluid
36 passage and the first radial passages and pressure sensitive
37 valves into the annular region to radially expand the
38 expandable tubular member.

1 21. The method of claim 20, wherein positioning the apparatus within the
2 borehole comprises:

3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the borehole.

1 22. The method of claim 20, further comprising:
2 positioning a top plug in the top throat passage.

1 23. A method of operating an apparatus for forming a wellbore casing within
2 a borehole within a subterranean formation, the apparatus comprising:
3 a first annular support member defining a first fluid passage and one or
4 more first radial passages having pressure sensitive valves fluidically
5 coupled to the first fluid passage;
6 an annular expansion cone coupled to the first annular support member;
7 an expandable tubular member movably coupled to the expansion cone;
8 a second annular support member defining a second fluid passage
9 coupled to the expandable tubular member;
10 an annular valve member defining a third fluid passage fluidically coupled
11 to the first and second fluid passages having top and bottom
12 throat passages, defining second and third radial passages fluidically
13 coupled to the third fluid passage, coupled to the second annular

14 support member, and movably coupled to the first annular support
15 member; and
16 an annular sleeve releasably coupled to the first annular support member
17 and movably coupled to the annular valve member for controllably
18 fluidicly coupling the second and third radial passages; and
19 wherein an annular region is defined by the region between the tubular
20 member and the first annular support member, the second
21 annular support member, the annular valve member, and the
22 annular sleeve;
23 the method comprising:
24 positioning the apparatus within the borehole;
25 injecting fluidic materials into the first, second and third fluid
26 passages;
27 positioning a bottom plug in the bottom throat passage;
28 injecting a non-hardenable fluidic material through the first fluid
29 passages and the first radial passages and pressure sensitive
30 valves into the annular region to radially expand a portion
31 of the expandable tubular member;
32 displacing the annular sleeve to fluidicly couple the second and
33 third radial passages;
34 injecting a hardenable fluidic sealing material through the first,
35 second, and third fluid passages, and the second and third
36 radial passages;
37 displacing the annular sleeve to fluidicly decouple the second and
38 third radial passages; and
39 injecting a non-hardenable fluidic material through the first fluid
40 passage and the first radial passages and pressure sensitive
41 valves into the annular region to radially expand another
42 portion of the expandable tubular member.

1 24. The method of claim 23, wherein positioning the apparatus within the
2 borehole comprises:

3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the borehole.

1 25. The method of claim 23, wherein positioning the apparatus within the
2 borehole comprises:

3 positioning an end of the expandable tubular member adjacent to a
4 preexisting section of wellbore casing within the borehole.

1 26. The method of claim 23, wherein injecting a non-hardenable fluidic
2 material into the first fluid passage and first radial passages and pressure
3 sensitive valves to radially expand a portion of the expandable tubular member
4 comprises:

5 injecting a non-hardenable fluidic material into the first fluid passage
6 and first radial passages and pressure sensitive valves to radially
7 expand the expandable tubular member until an end portion of
8 the tubular member is positioned proximate the bottom of the
9 borehole.

1 27. The method of claim 23, further comprising:
2 positioning a top plug in the top throat passage.

1 28. A method of coupling an expandable tubular member to a preexisting
2 structure, comprising:
3 positioning the expandable tubular member within the preexisting
4 structure;
5 injecting fluidic materials into the expandable tubular member;
6 fluidically isolating a first region from a second region within the
7 expandable tubular member;
8 fluidically coupling the first and second regions;
9 injecting a hardenable fluidic sealing material into the expandable
10 tubular member;
11 fluidically decoupling the first and second regions; and

12 injecting a non-hardenable fluidic material into the expandable tubular
13 member to radially expand the tubular member.

1 29. The method of claim 28, wherein positioning the expandable tubular
2 member within the preexisting structure comprises:
3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the preexisting structure.

1 30. The method of claim 28, further comprising:
2 fluidically isolating the second region from a third region within the
3 expandable tubular member.

1 31. An apparatus for coupling an expandable tubular member to a
2 preexisting structure, comprising:
3 means for positioning the expandable tubular member within the
4 preexisting structure;
5 means for injecting fluidic materials into the expandable tubular
6 member;
7 means for fluidically isolating a first region from a second region within
8 the expandable tubular member;
9 means for fluidically coupling the first and second regions;
10 means for injecting a hardenable fluidic sealing material into the
11 expandable tubular member;
12 means for fluidically decoupling the first and second regions; and
13 means for injecting a non-hardenable fluidic material into the
14 expandable tubular member to radially expand the tubular
15 member.

1 32. The apparatus of claim 31, wherein the means for positioning the
2 expandable tubular member within the preexisting structure comprises:
3 means for positioning an end of the expandable tubular member adjacent
4 to the bottom of the preexisting structure.

1 33. The apparatus of claim 31, further comprising:
2 means for fluidicly isolating the second region from a third region within
3 the expandable tubular member.

1 34. A method of coupling an expandable tubular member to a preexisting
2 structure, comprising:
3 positioning the expandable tubular member within the preexisting
4 structure;
5 injecting fluidic materials into the expandable tubular member;
6 fluidicly isolating a first region from a second region within the
7 expandable tubular member;
8 injecting a non-hardenable fluidic material into the expandable tubular
9 member to radially expand at least a portion of the tubular
10 member;
11 fluidicly coupling the first and second regions;
12 injecting a hardenable fluidic sealing material into the expandable
13 tubular member;
14 fluidicly decoupling the first and second regions; and
15 injecting a non-hardenable fluidic material into the expandable tubular
16 member to radially expand another portion of the tubular
17 member.

1 35. The method of claim 34, wherein positioning the expandable tubular
2 member within the preexisting structure comprises:
3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the preexisting structure.

1 36. The method of claim 34, wherein positioning the expandable tubular
2 member within the preexisting structure comprises:

3 positioning an end of the expandable tubular member adjacent to a
4 preexisting tubular structural element within the preexisting
5 structure.

1 37. The method of claim 34, wherein injecting a non-hardenable fluidic
2 material into the expandable tubular member to radially expand at least a
3 portion of the tubular member comprises:
4 injecting a non-hardenable fluidic material into the expandable tubular
5 member to radially expand at least a portion of the tubular
6 member until an end portion of the tubular member is positioned
7 proximate the bottom of the preexisting structure.

1 38. The method of claim 34, further comprising:
2 fluidically isolating the second region from a third region within the
3 expandable tubular member.

1 39. An apparatus for coupling an expandable tubular member to a
2 preexisting structure, comprising:
3 means for positioning the expandable tubular member within the
4 preexisting structure;
5 means for injecting fluidic materials into the expandable tubular
6 member;
7 means for fluidically isolating a first region from a second region within
8 the expandable tubular member;
9 means for injecting a non-hardenable fluidic material into the
10 expandable tubular member to radially expand at least a portion of
11 the tubular member;
12 means for fluidically coupling the first and second regions;
13 means for injecting a hardenable fluidic sealing material into the
14 expandable tubular member;
15 means for fluidically decoupling the first and second regions; and

16 means for injecting a non-hardenable fluidic material into the
17 expandable tubular member to radially expand another portion of
18 the tubular member.

1 40. The apparatus of claim 39, wherein means for positioning the expandable
2 tubular member within the preexisting structure comprises:

3 means for positioning an end of the expandable tubular member adjacent
4 to the bottom of the preexisting structure.

1 41. The apparatus of claim 39, wherein means for positioning the expandable
2 tubular member within the preexisting structure comprises:

3 means for positioning an end of the expandable tubular member adjacent
4 to a preexisting structural element within the preexisting
5 structure.

1 42. The apparatus of claim 39, wherein means for injecting a non-hardenable
2 fluidic material into the expandable tubular member to radially expand at least
3 a portion of the tubular member comprises:

4 means for injecting a non-hardenable fluidic material into the
5 expandable tubular member to radially expand at least a portion of
6 the tubular member until an end portion of the tubular member is
7 positioned proximate the bottom of the preexisting structure.

1 43. The apparatus of claim 39, further comprising:

2 means for fluidically isolating the second region from a third region within
3 the expandable tubular member.

1 44. An apparatus for coupling an expandable tubular member to a
2 preexisting structure, comprising:
3 a first annular support member defining a first fluid passage and one or
4 more first radial passages having pressure sensitive valves fluidically
5 coupled to the first fluid passage;
6 an annular expansion cone coupled to the first annular support member;
7 an expandable tubular member movably coupled to the expansion cone;
8 a second annular support member defining a second fluid passage
9 coupled to the expandable tubular member;
10 an annular valve member defining a third fluid passage fluidically coupled
11 to the first and second fluid passages having first and second
12 throat passages, defining second and third radial passages fluidically
13 coupled to the third fluid passage, coupled to the second annular
14 support member, and movably coupled to the first annular support
15 member; and
16 an annular sleeve releasably coupled to the first annular support member
17 and movably coupled to the annular valve member for controllably
18 fluidically coupling the second and third radial passages; and
19 wherein an annular region is defined by the region between the tubular
20 member and the first annular support member, the second
21 annular support member, the annular valve member, and the
22 annular sleeve.

1 45. An apparatus for coupling an expandable tubular member to a
2 preexisting structure, comprising:
3 means for radially expanding an expandable tubular member; and
4 means for injecting a hardenable fluidic sealing material into an annulus
5 between the expandable tubular member and the borehole.

1 46. The apparatus of claim 45, wherein the means for injecting a hardenable
2 fluidic sealing material into an annulus between the expandable tubular
3 member and the borehole, comprises:

4 a sliding sleeve valve.

1 47. A method of operating an apparatus for coupling an expandable tubular
2 member to a preexisting structure, the apparatus comprising:

3 a first annular support member defining a first fluid passage and one or
4 more first radial passages having pressure sensitive valves fluidically
5 coupled to the first fluid passage;

6 an annular expansion cone coupled to the first annular support member;

7 an expandable tubular member movably coupled to the expansion cone;

8 a second annular support member defining a second fluid passage

9 coupled to the expandable tubular member;

10 an annular valve member defining a third fluid passage fluidically coupled

11 to the first and second fluid passages having top and bottom

12 throat passages, defining second and third radial passages fluidically

13 coupled to the third fluid passage, coupled to the second annular

14 support member, and movably coupled to the first annular support

15 member; and

16 an annular sleeve releasably coupled to the first annular support member

17 and movably coupled to the annular valve member for controllably

18 fluidically coupling the second and third radial passages; and

19 wherein an annular region is defined by the region between the tubular

20 member and the first annular support member, the second

21 annular support member, the annular valve member, and the

22 annular sleeve;

23 the method comprising:

24 positioning the apparatus within the preexisting structure;

25 injecting fluidic materials into the first, second and third fluid

26 passages;

27 positioning a bottom plug in the bottom throat passage;

28 displacing the annular sleeve to fluidically couple the second and

29 third radial passages;

30 injecting a hardenable fluidic sealing material through the first,
31 second, and third fluid passages, and the second and third
32 radial passages;
33 displacing the annular sleeve to fluidically decouple the second and
34 third radial passages; and
35 injecting a non-hardenable fluidic material through the first fluid
36 passage and the first radial passages and pressure sensitive
37 valves into the annular region to radially expand the
38 expandable tubular member.

1 48. The method of claim 47, wherein positioning the apparatus within the
2 preexisting structure comprises:
3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the preexisting structure.

1 49. The method of claim 47, further comprising:
2 positioning a top plug in the top throat passage.

1 50. A method of operating an apparatus for coupling an expandable tubular
2 member to a preexisting structure, the apparatus comprising:
3 a first annular support member defining a first fluid passage and one or
4 more first radial passages having pressure sensitive valves fluidically
5 coupled to the first fluid passage;
6 an annular expansion cone coupled to the first annular support member;
7 an expandable tubular member movably coupled to the expansion cone;
8 a second annular support member defining a second fluid passage
9 coupled to the expandable tubular member;
10 an annular valve member defining a third fluid passage fluidically coupled
11 to the first and second fluid passages having top and bottom
12 throat passages, defining second and third radial passages fluidically
13 coupled to the third fluid passage, coupled to the second annular

14 support member, and movably coupled to the first annular support
15 member; and
16 an annular sleeve releasably coupled to the first annular support member
17 and movably coupled to the annular valve member for controllably
18 fluidically coupling the second and third radial passages; and
19 wherein an annular region is defined by the region between the tubular
20 member and the first annular support member, the second
21 annular support member, the annular valve member, and the
22 annular sleeve;
23 the method comprising:
24 positioning the apparatus within the preexisting structure;
25 injecting fluidic materials into the first, second and third fluid
26 passages;
27 positioning a bottom plug in the bottom throat passage;
28 injecting a non-hardenable fluidic material through the first fluid
29 passages and the first radial passages and pressure sensitive
30 valves into the annular region to radially expand a portion
31 of the expandable tubular member;
32 displacing the annular sleeve to fluidically couple the second and
33 third radial passages;
34 injecting a hardenable fluidic sealing material through the first,
35 second, and third fluid passages, and the second and third
36 radial passages;
37 displacing the annular sleeve to fluidically decouple the second and
38 third radial passages; and
39 injecting a non-hardenable fluidic material through the first fluid
40 passage and the first radial passages and pressure sensitive
41 valves into the annular region to radially expand another
42 portion of the expandable tubular member.

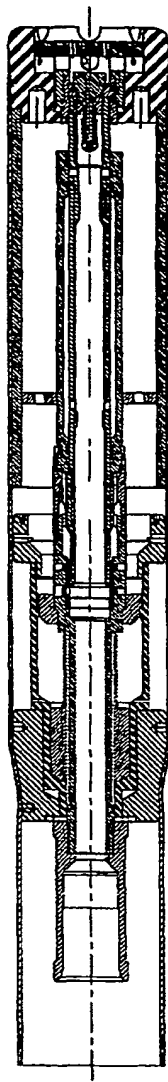
1 51. The method of claim 50, wherein positioning the apparatus within the
2 preexisting structure comprises:

3 positioning an end of the expandable tubular member adjacent to the
4 bottom of the preexisting structure.

1 52. The method of claim 50, wherein positioning the apparatus within the
2 preexisting structure comprises:
3 positioning an end of the expandable tubular member adjacent to a
4 preexisting section of a structural element within the preexisting
5 structure.

1 53. The method of claim 50, wherein injecting a non-hardenable fluidic
2 material into the first fluid passage and first radial passages and pressure
3 sensitive valves to radially expand a portion of the expandable tubular member
4 comprises:
5 injecting a non-hardenable fluidic material into the first fluid passage
6 and first radial passages and pressure sensitive valves to radially
7 expand the expandable tubular member until an end portion of
8 the tubular member is positioned proximate the bottom of the
9 preexisting structure.

1 54. The method of claim 50, further comprising:
2 positioning a top plug in the top throat passage.



10 ↗

Fig. 1

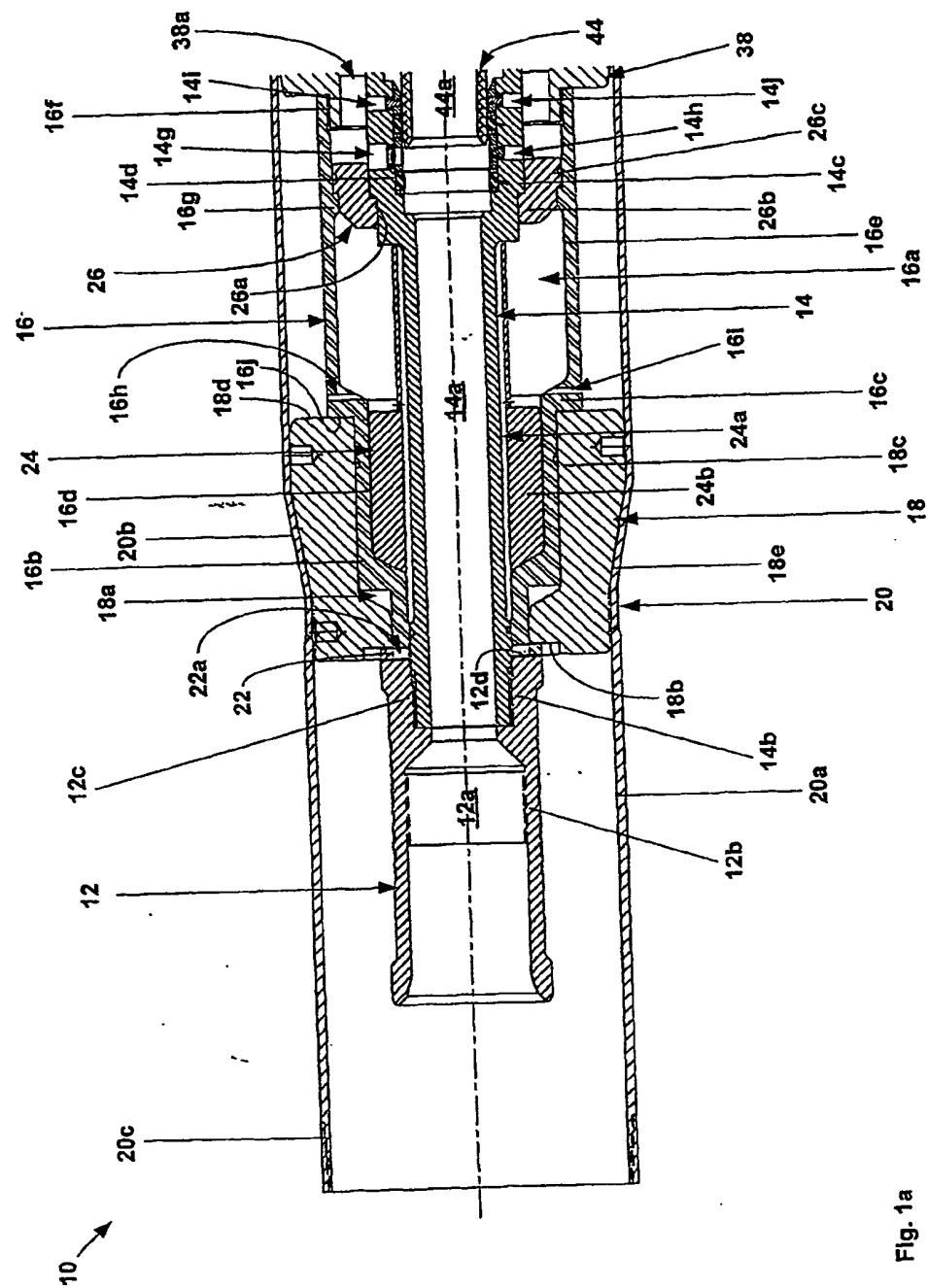
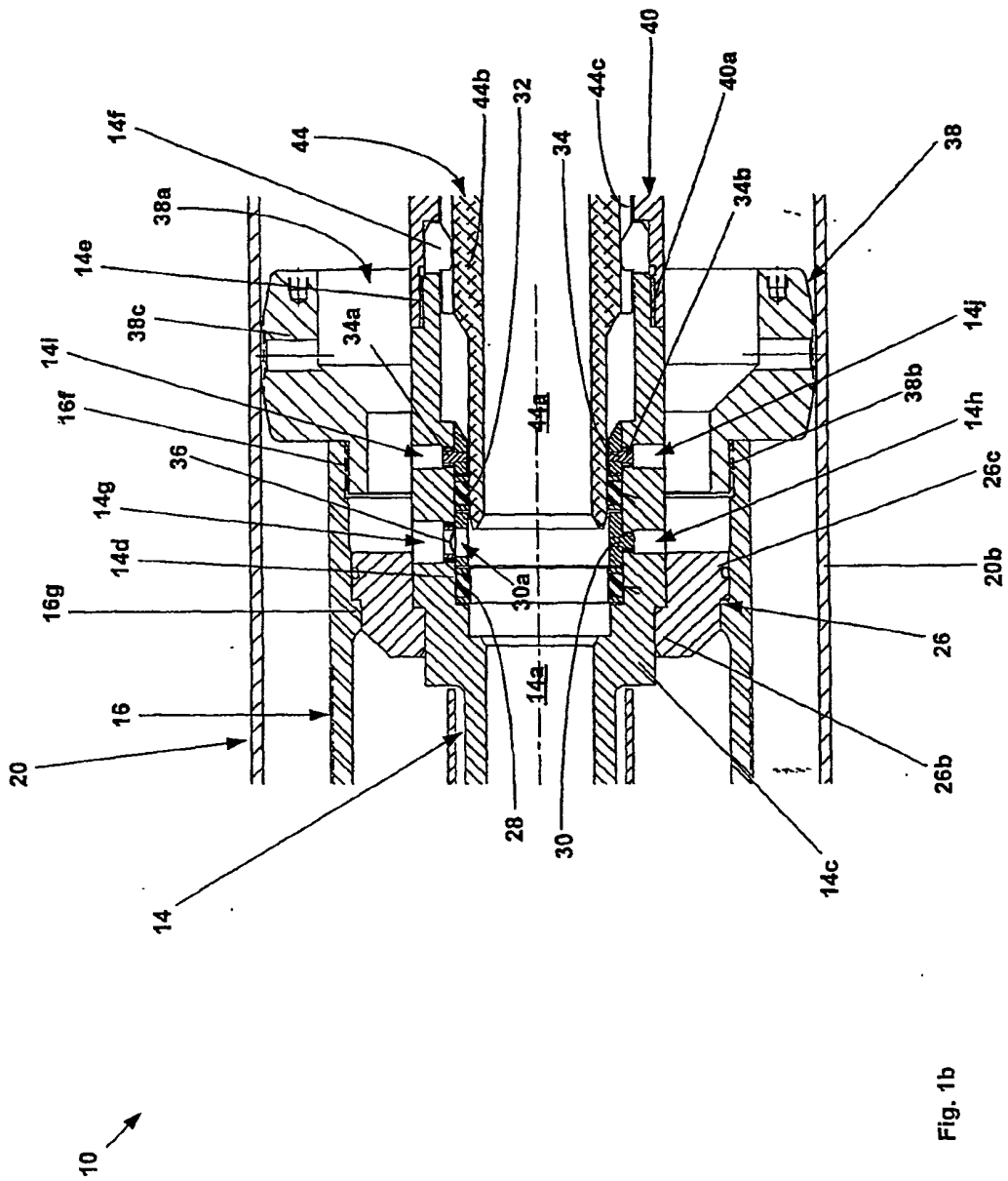


Fig. 1a



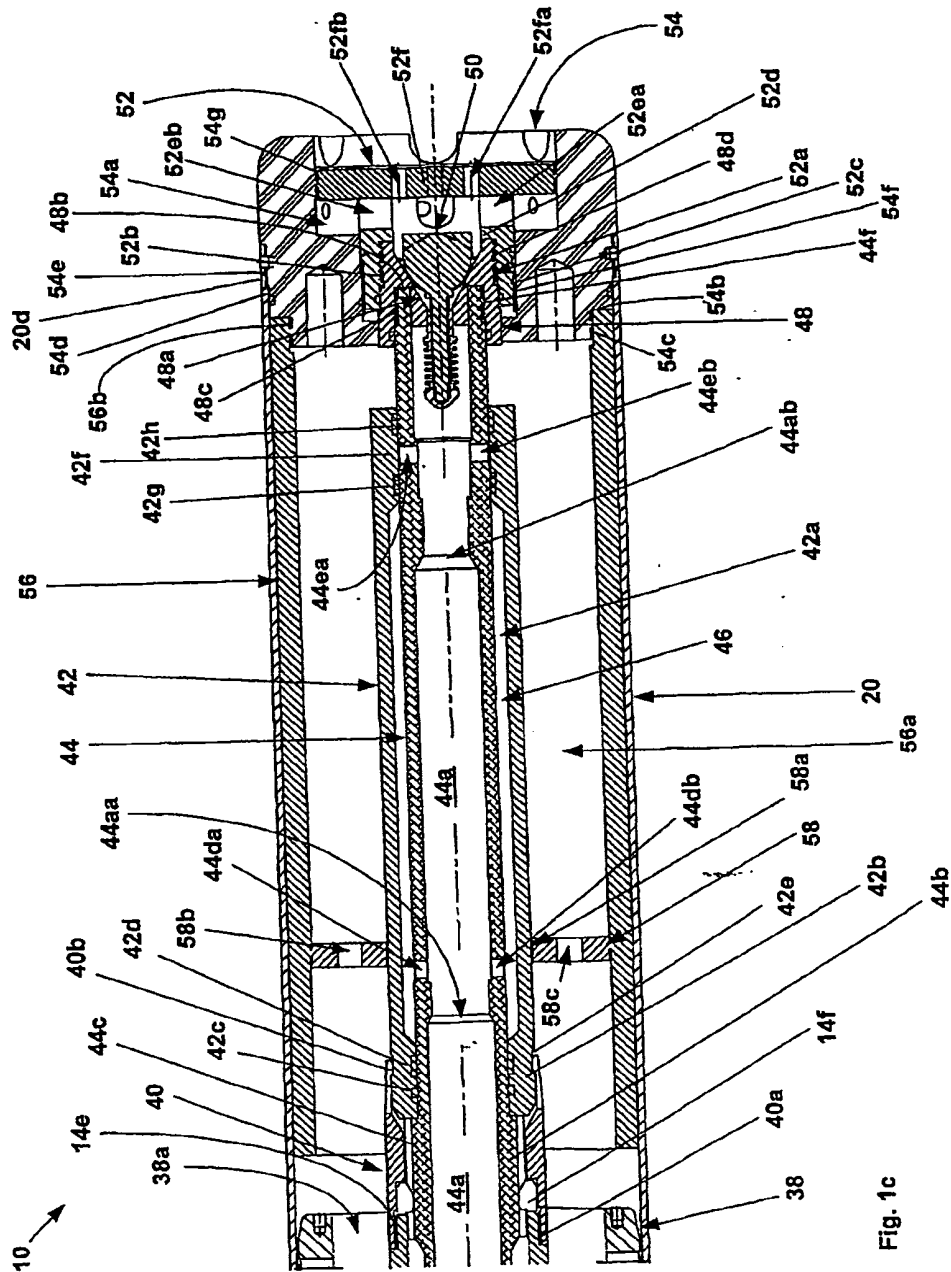


Fig. 1c

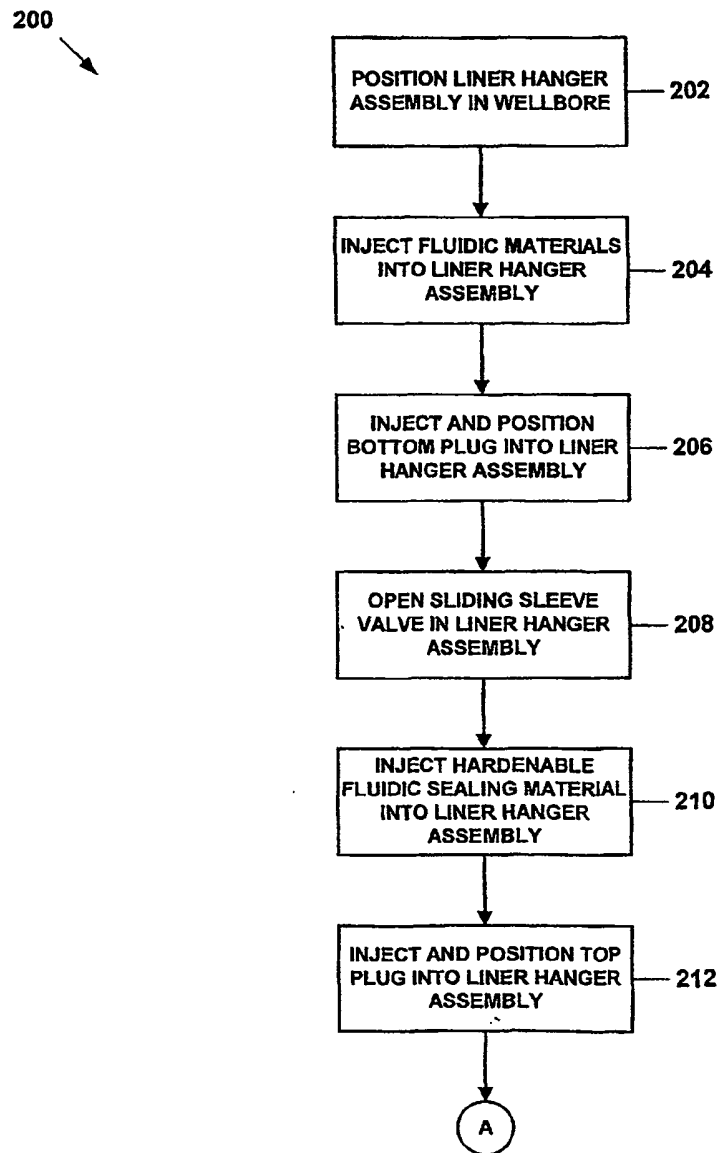


Fig. 2a

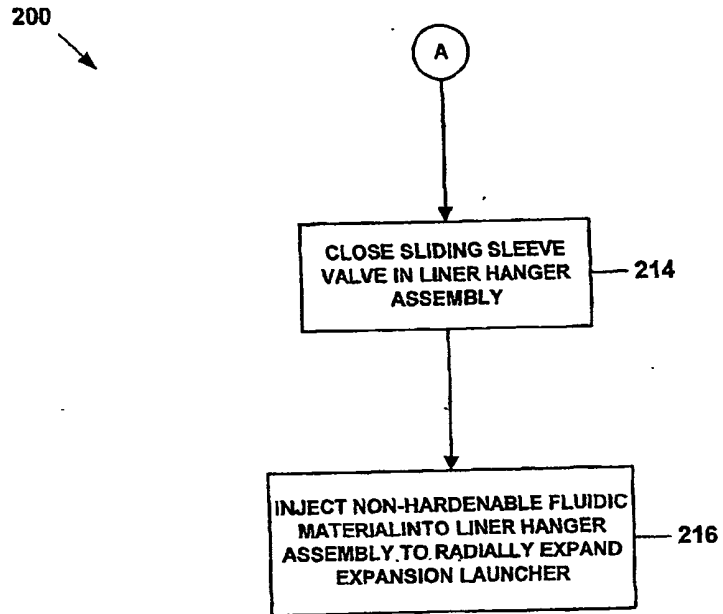


Fig. 2b

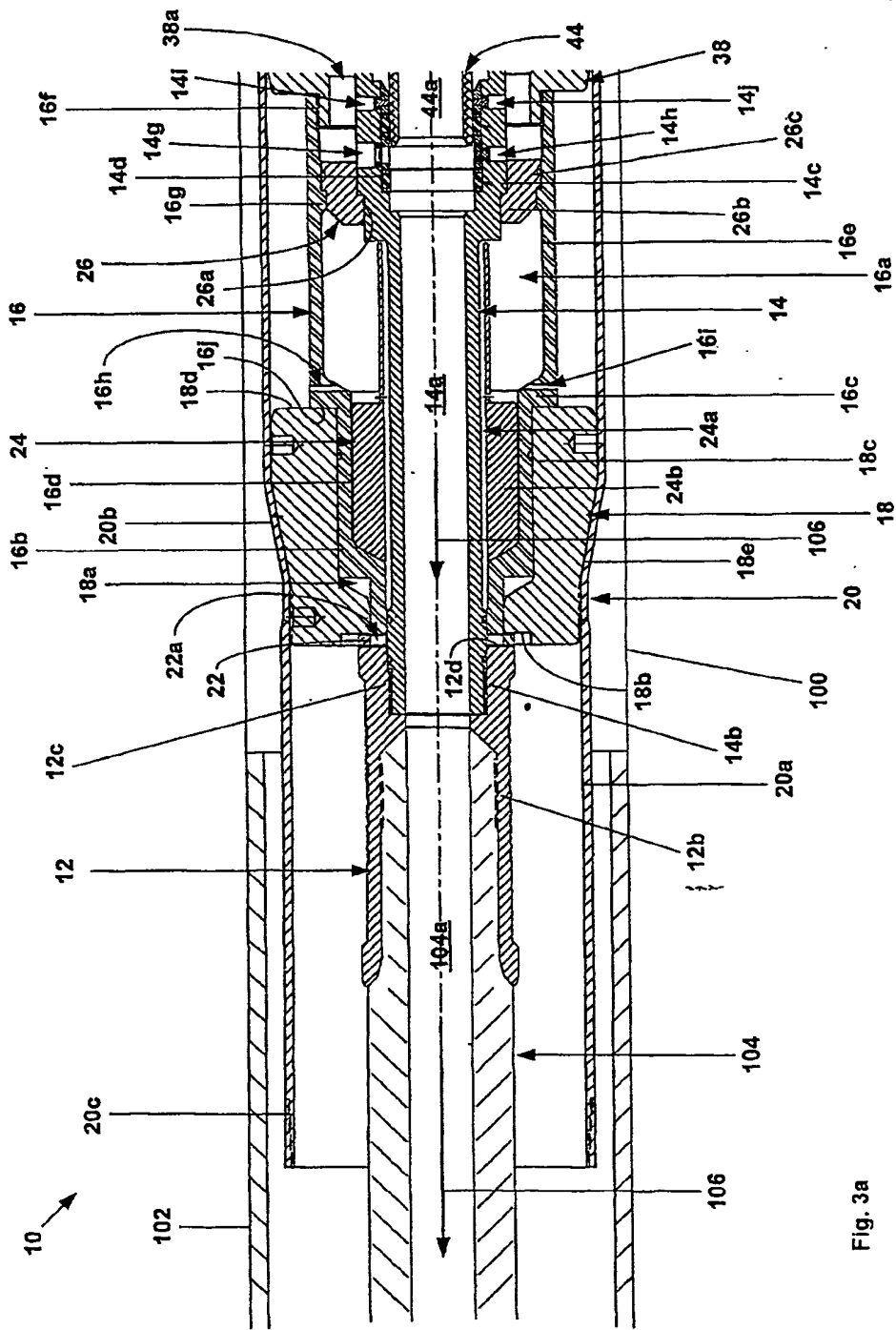
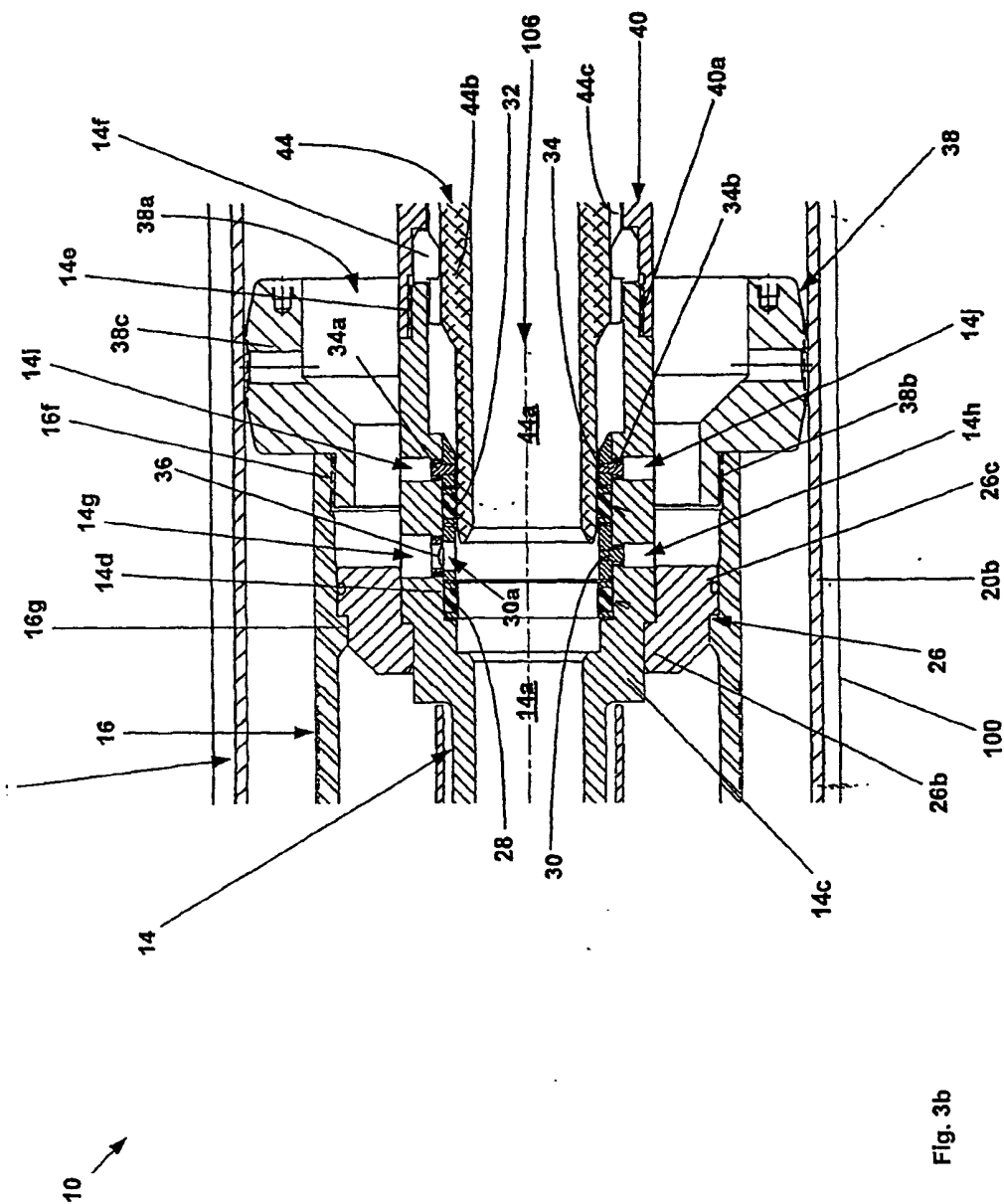


Fig. 3a



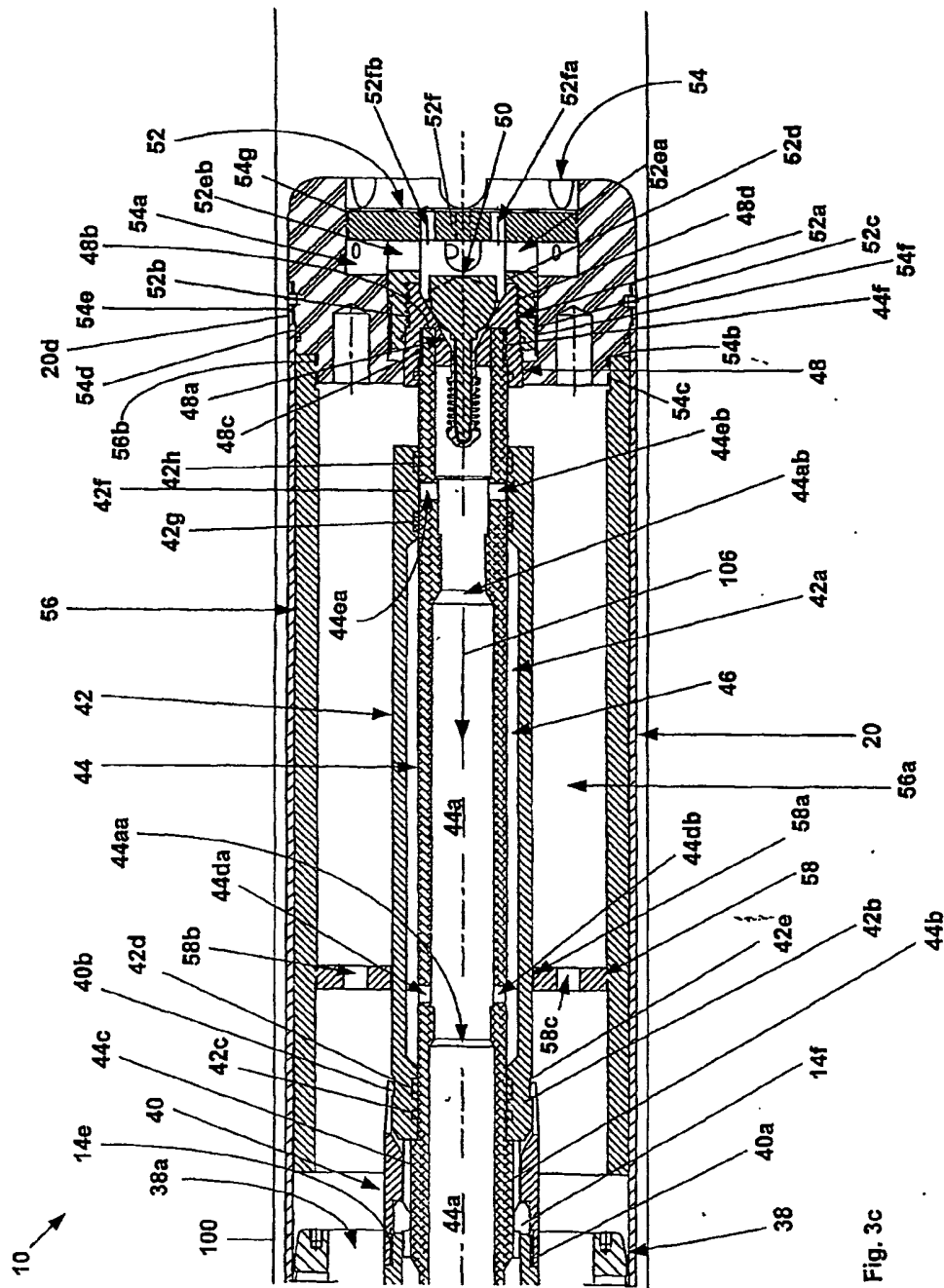


Fig. 3c

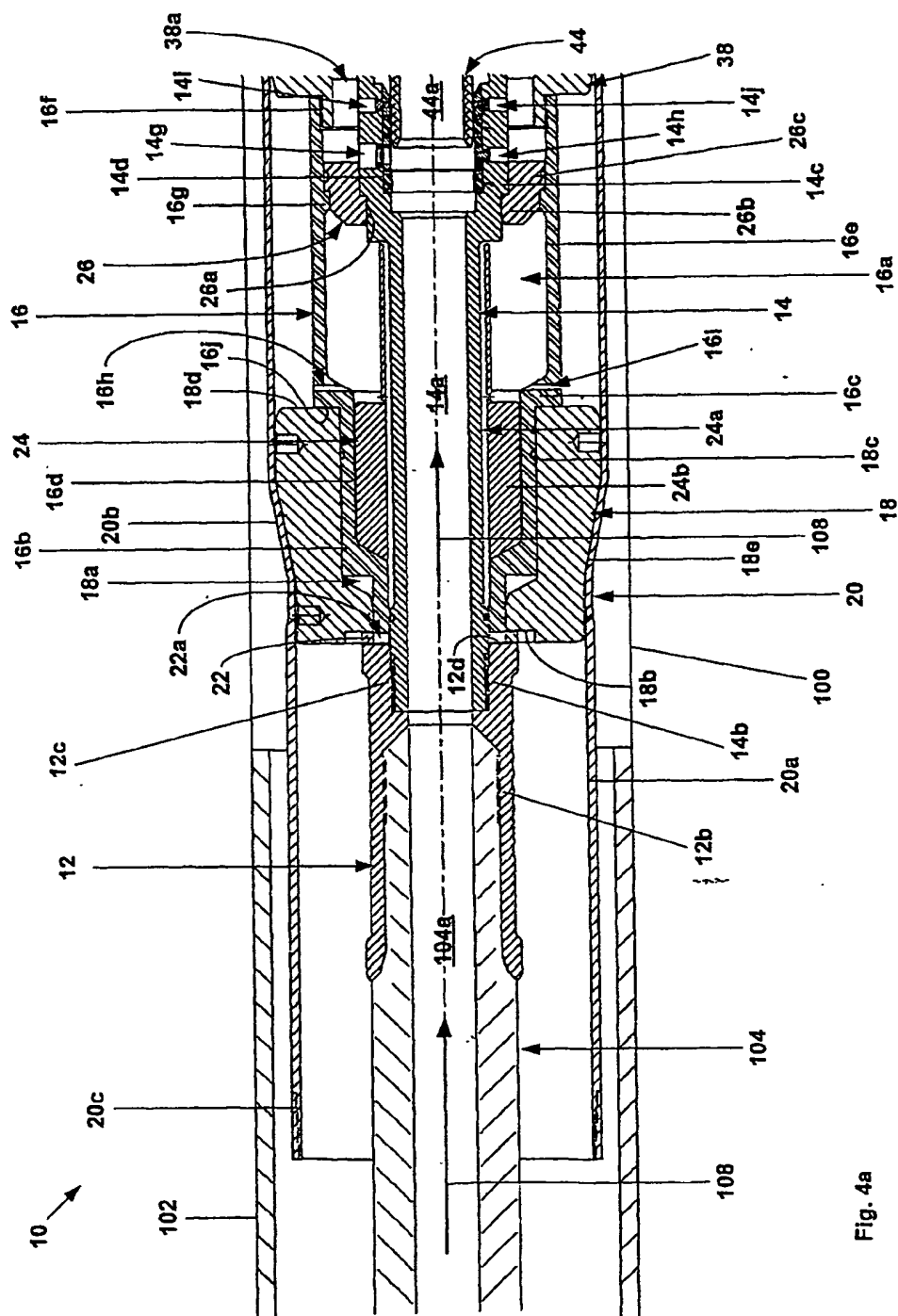


Fig. 4a

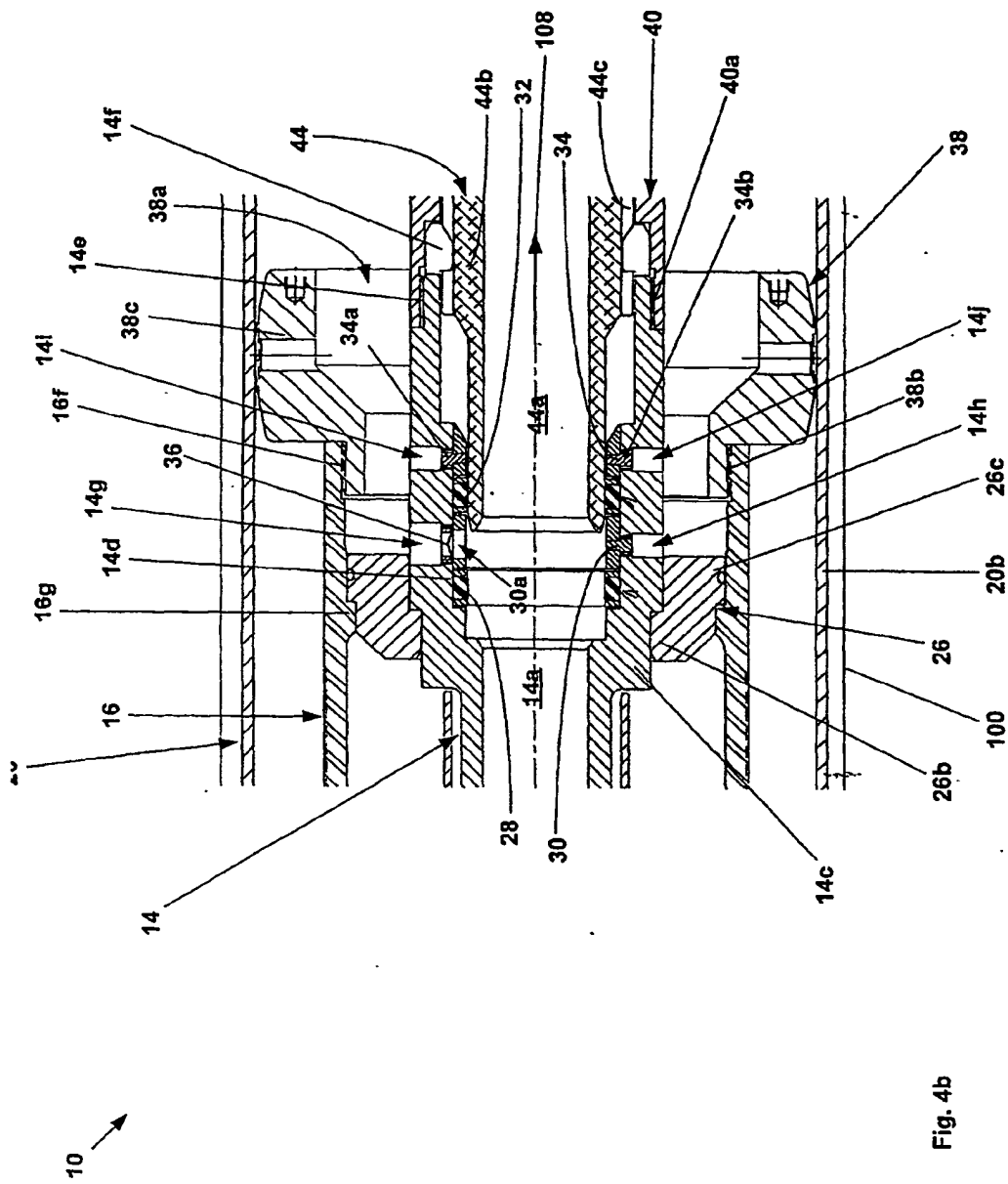


Fig. 4b

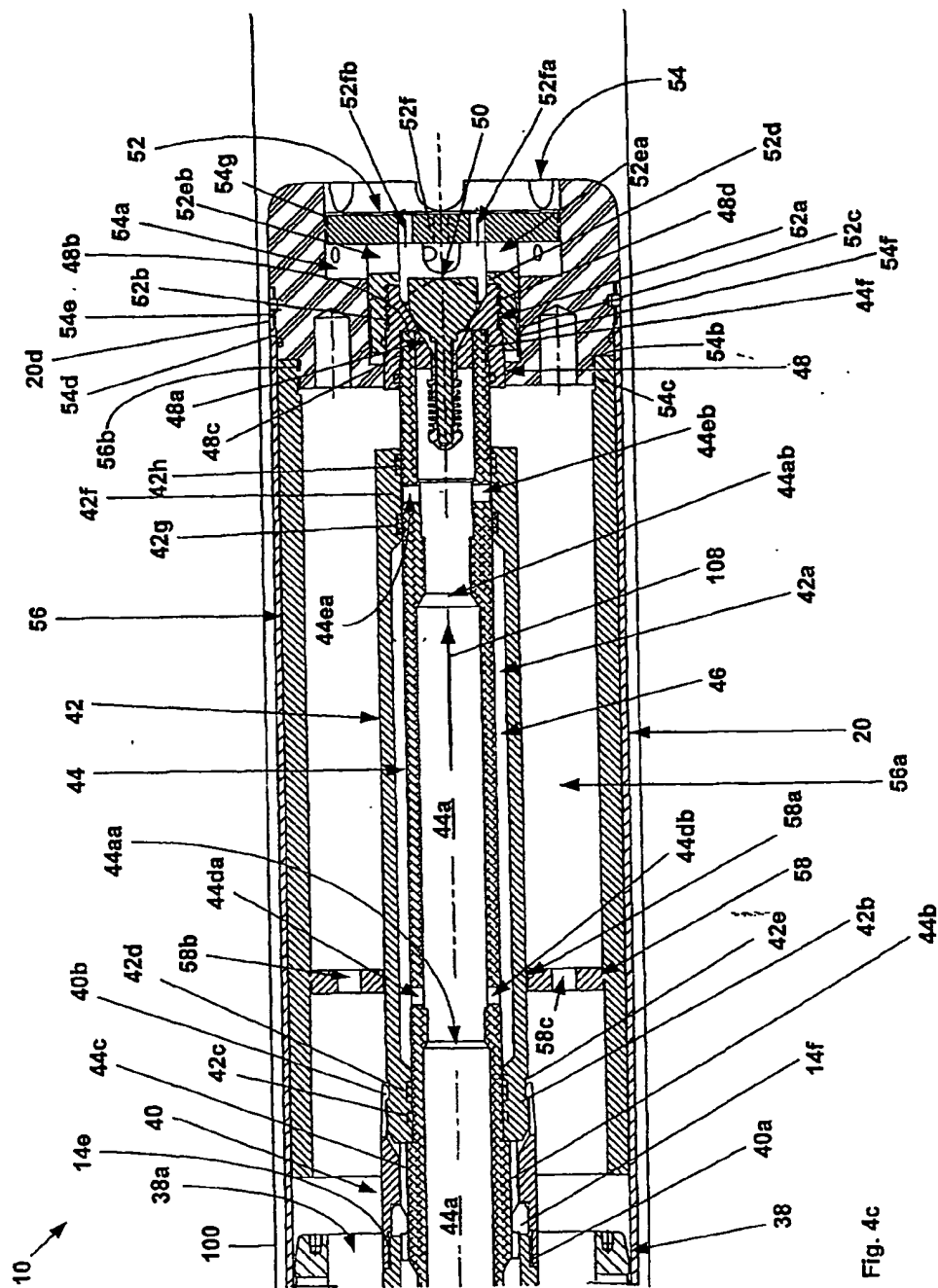


Fig. 4c

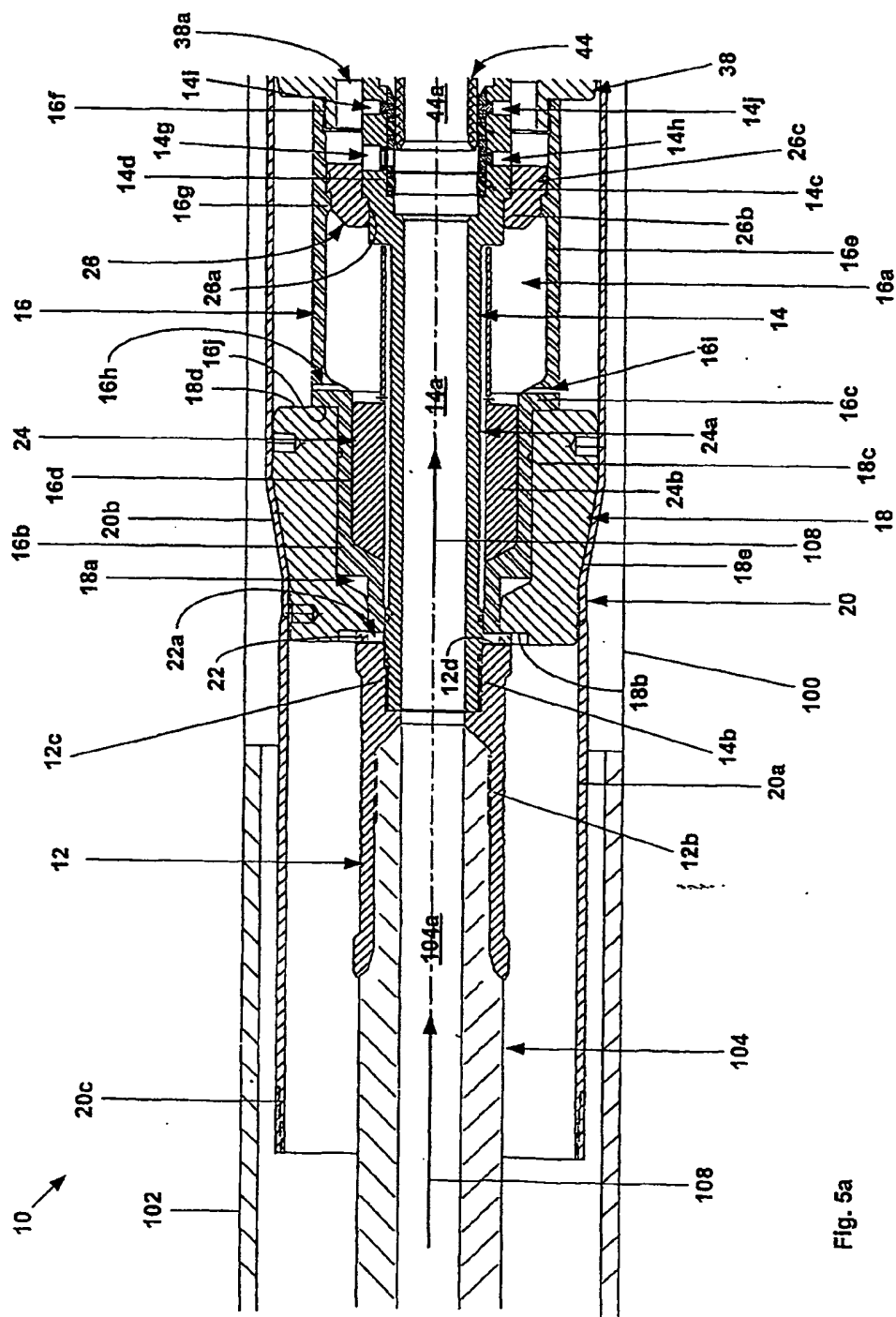
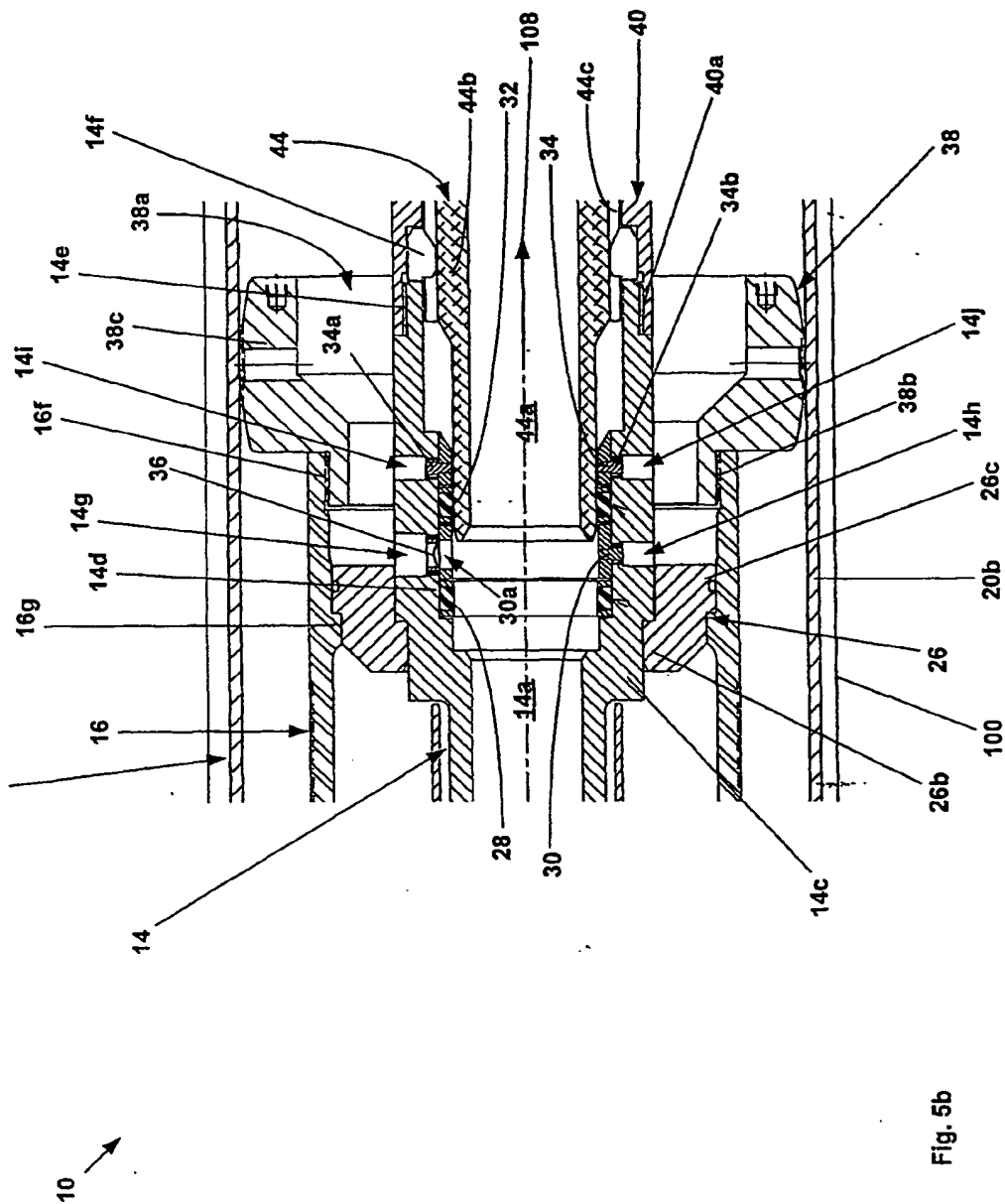
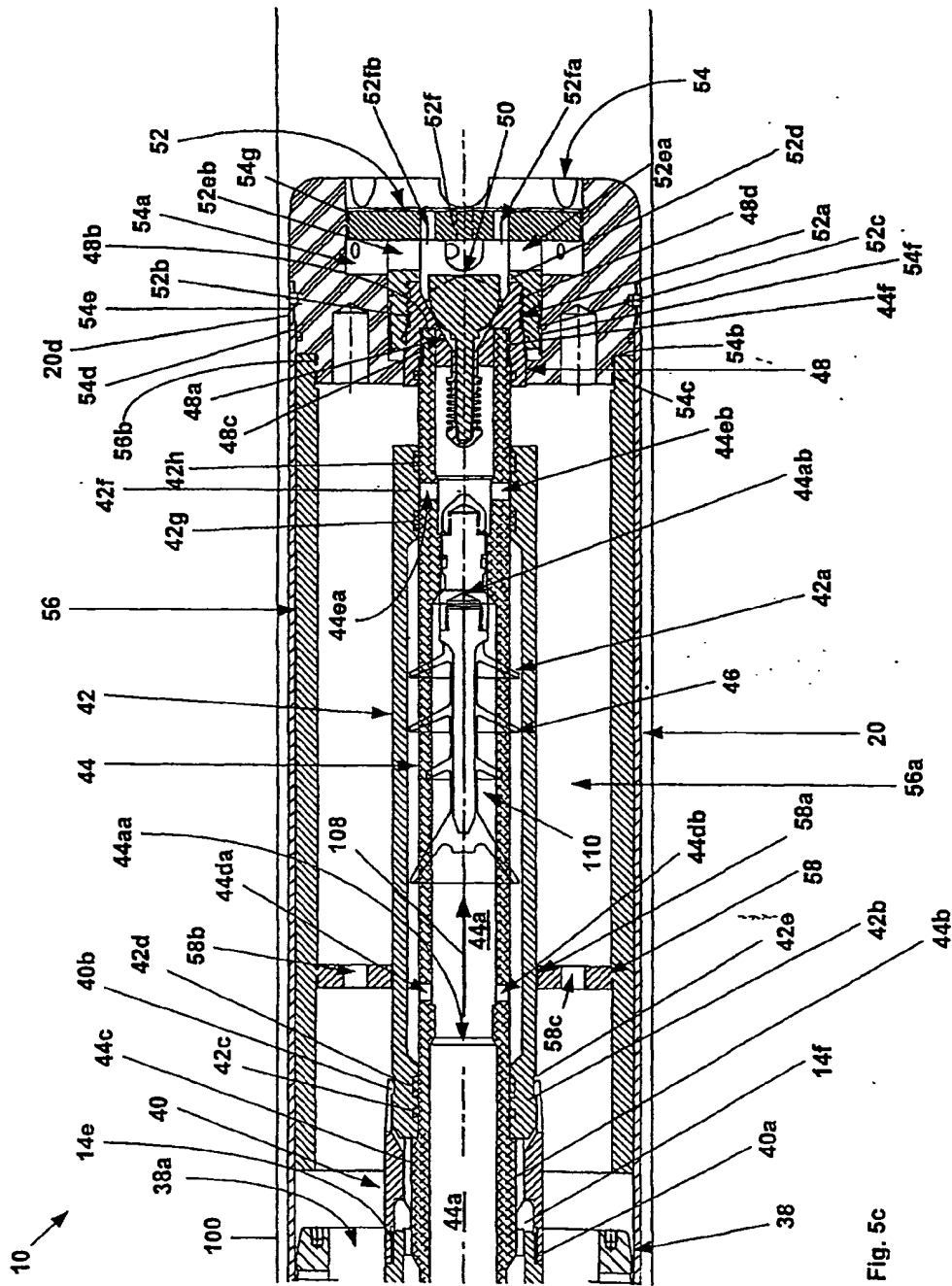


Fig. 5a





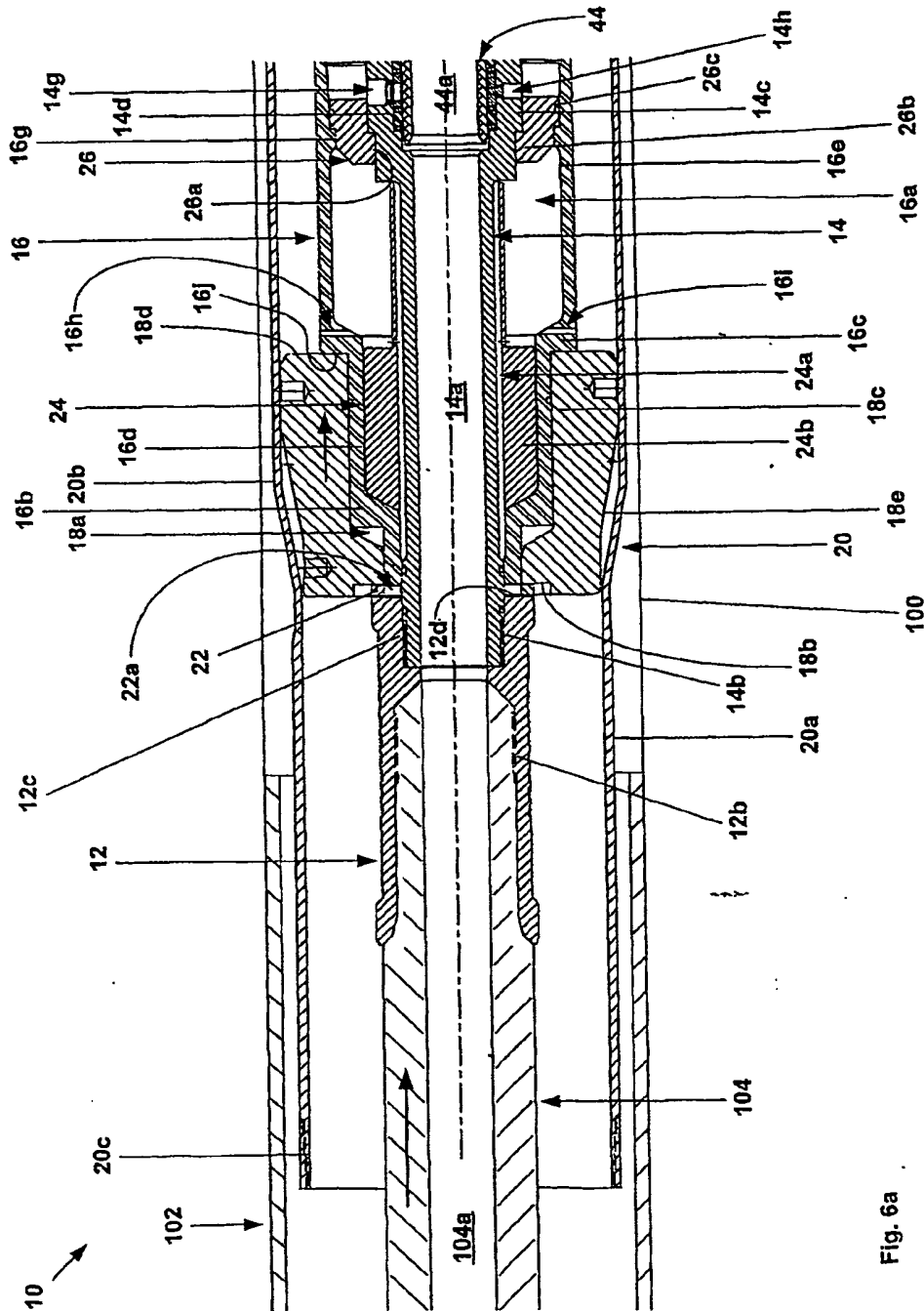


Fig. 6a

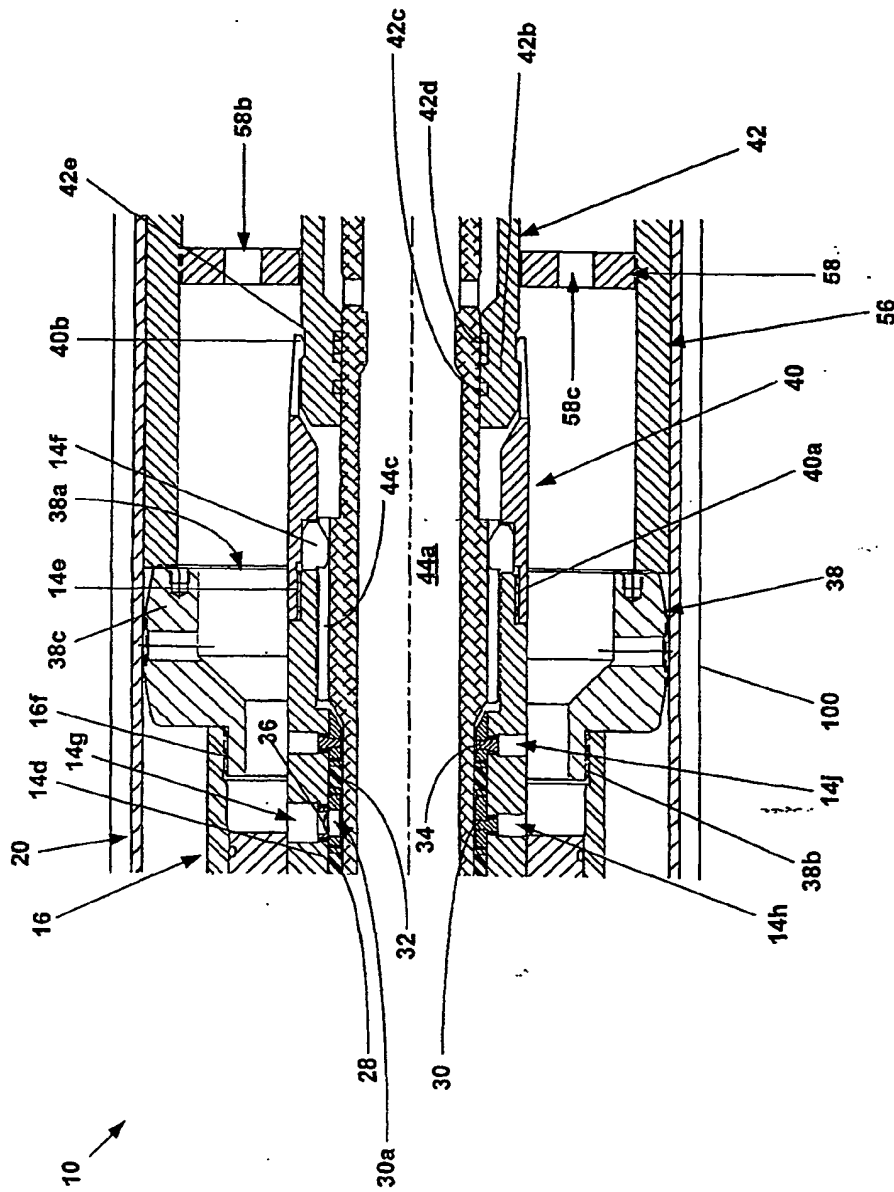


Fig. 6b

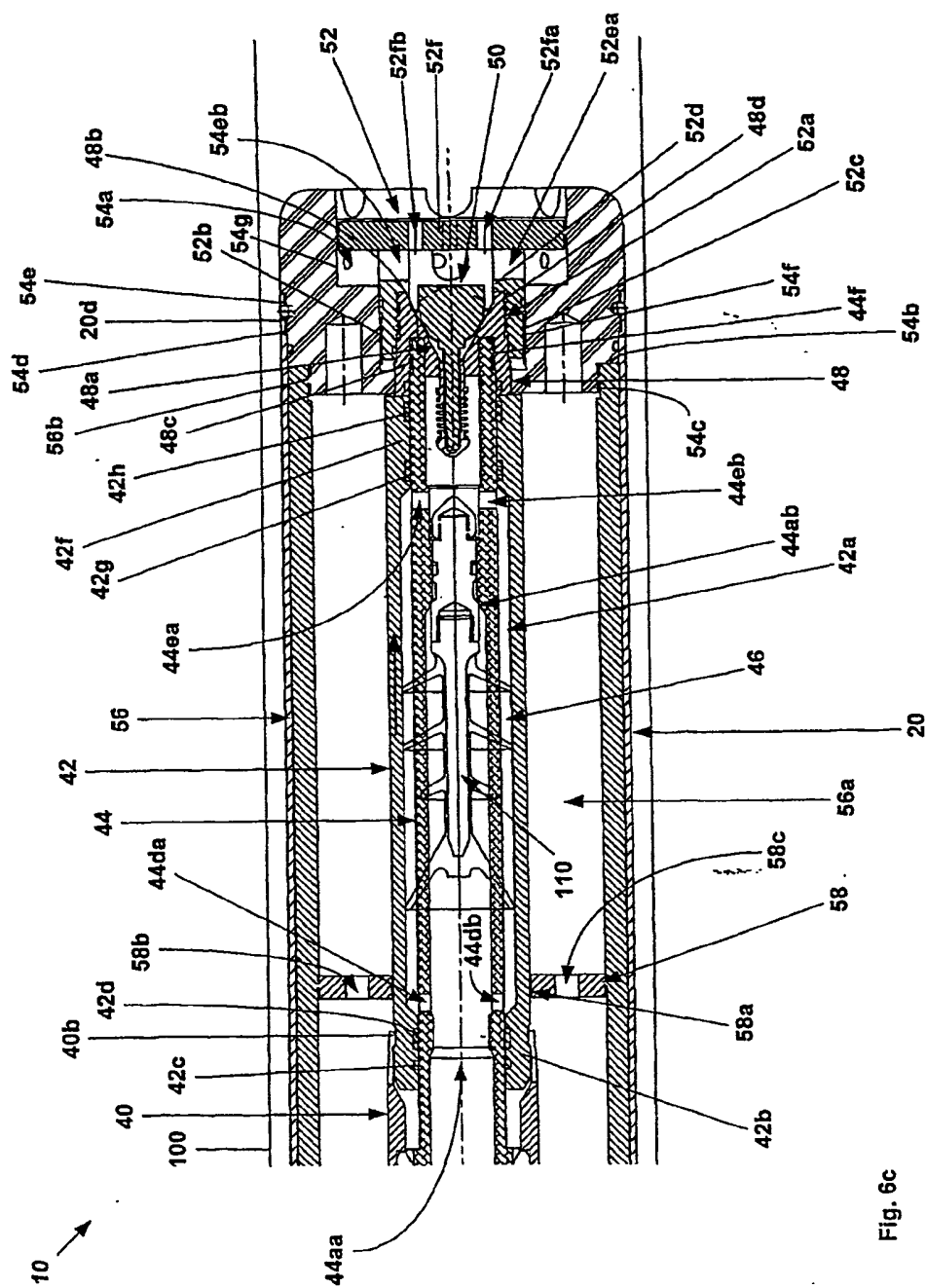


Fig. 6c

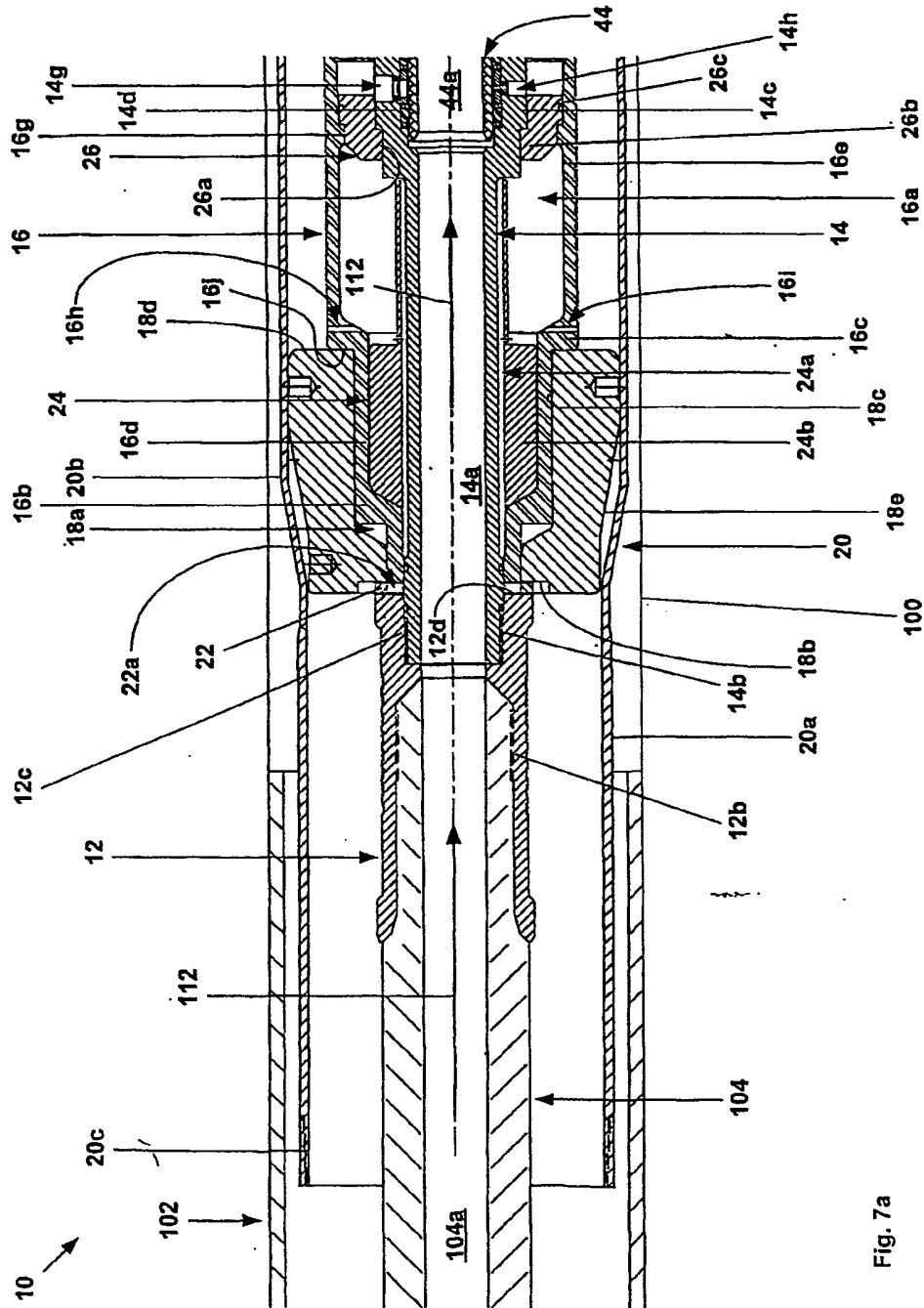


Fig. 7a

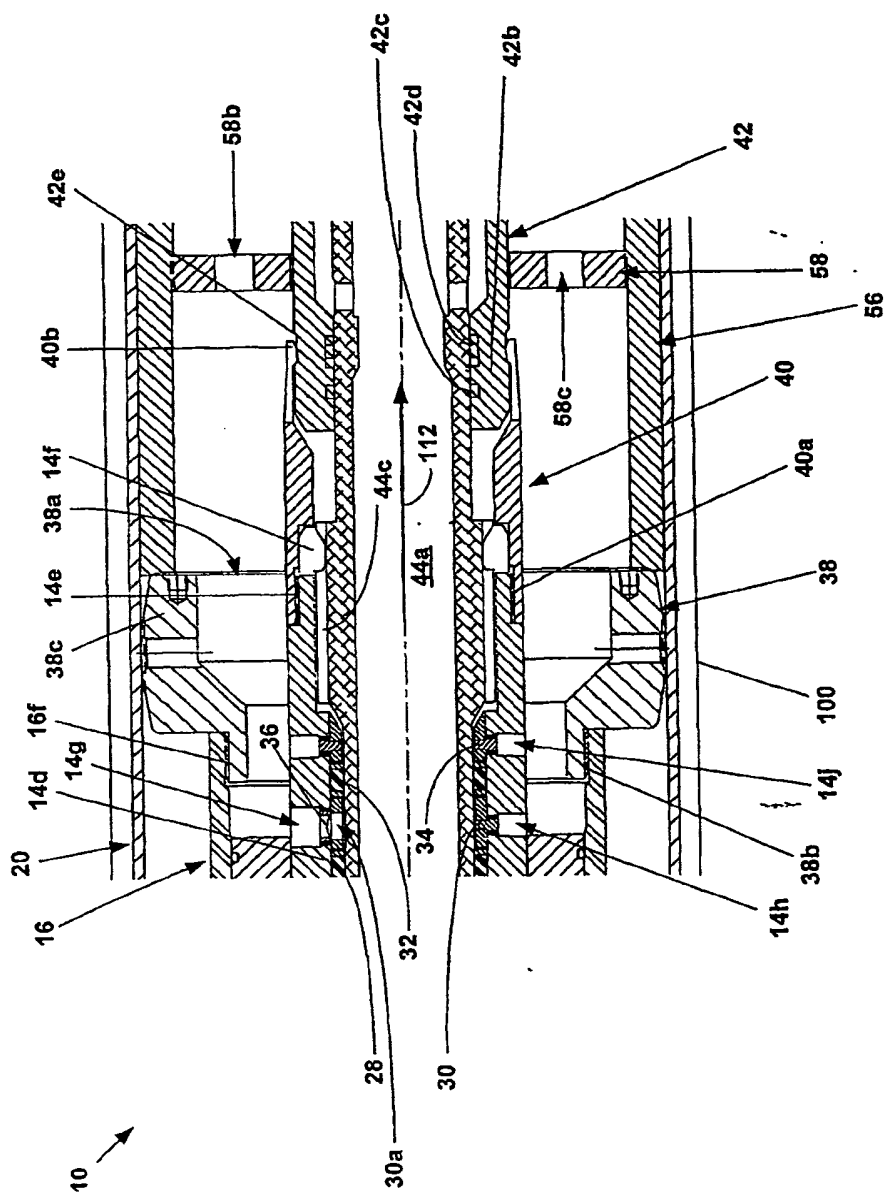


Fig. 7b

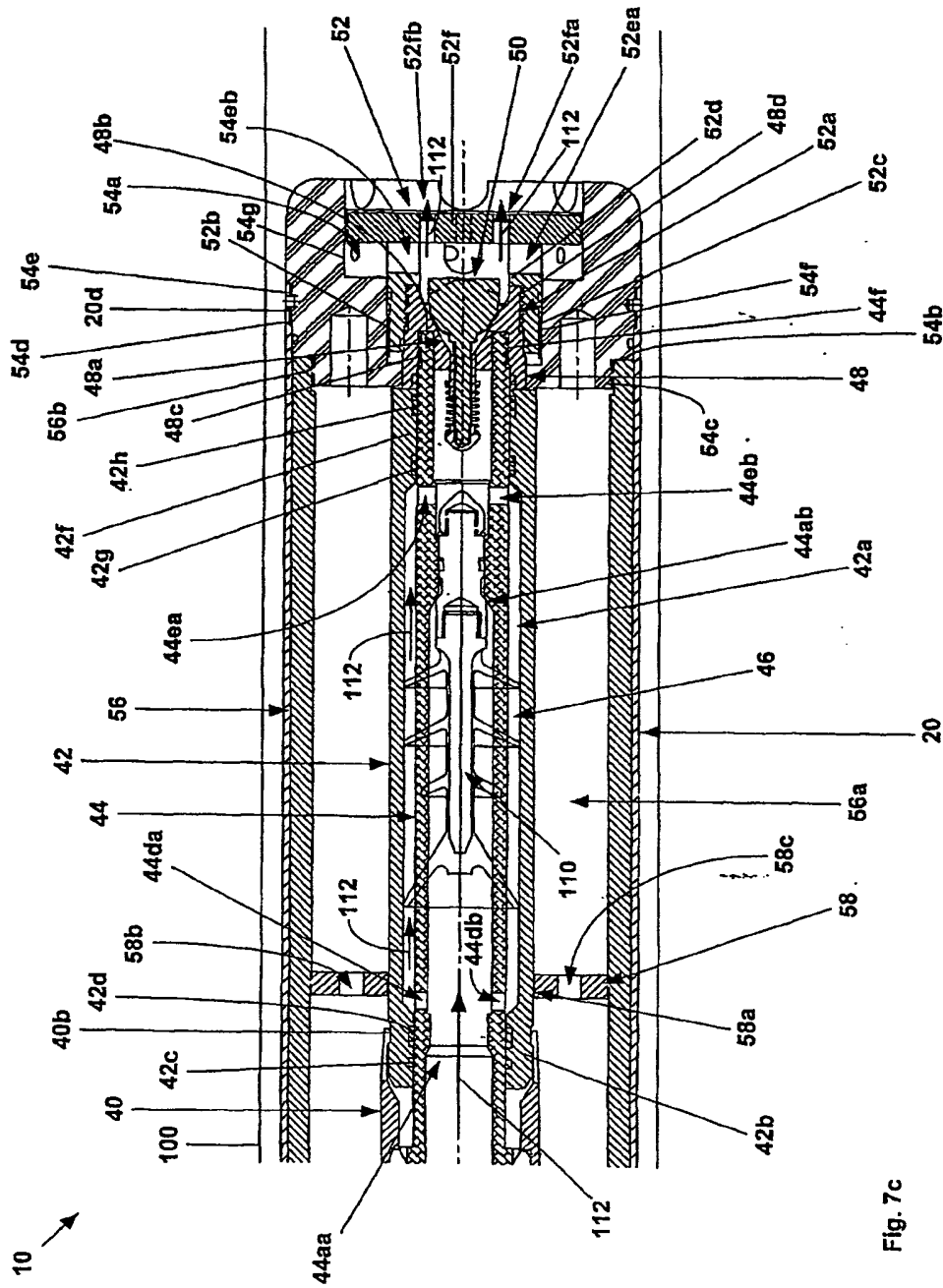


Fig. 7c

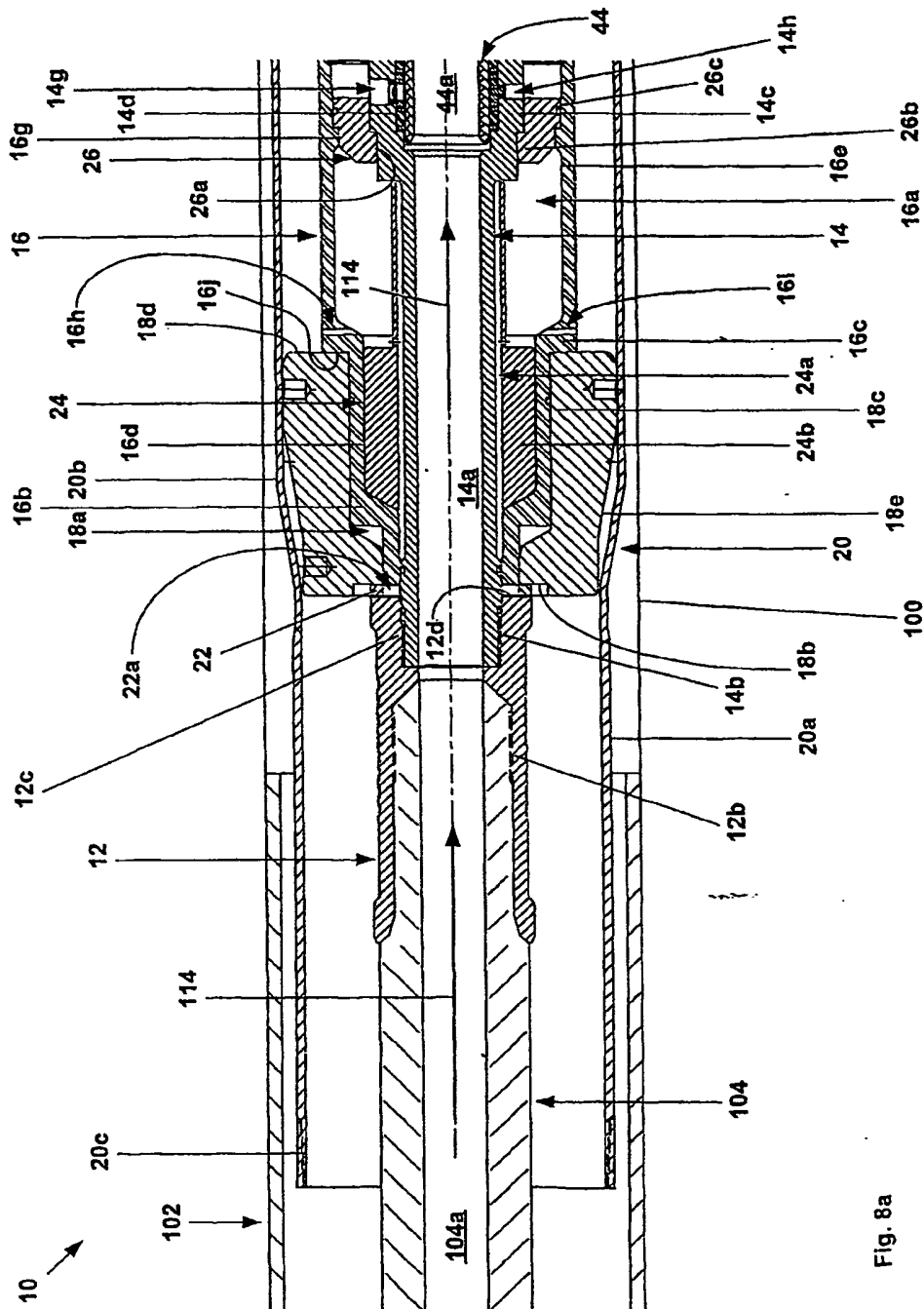


Fig. 8a

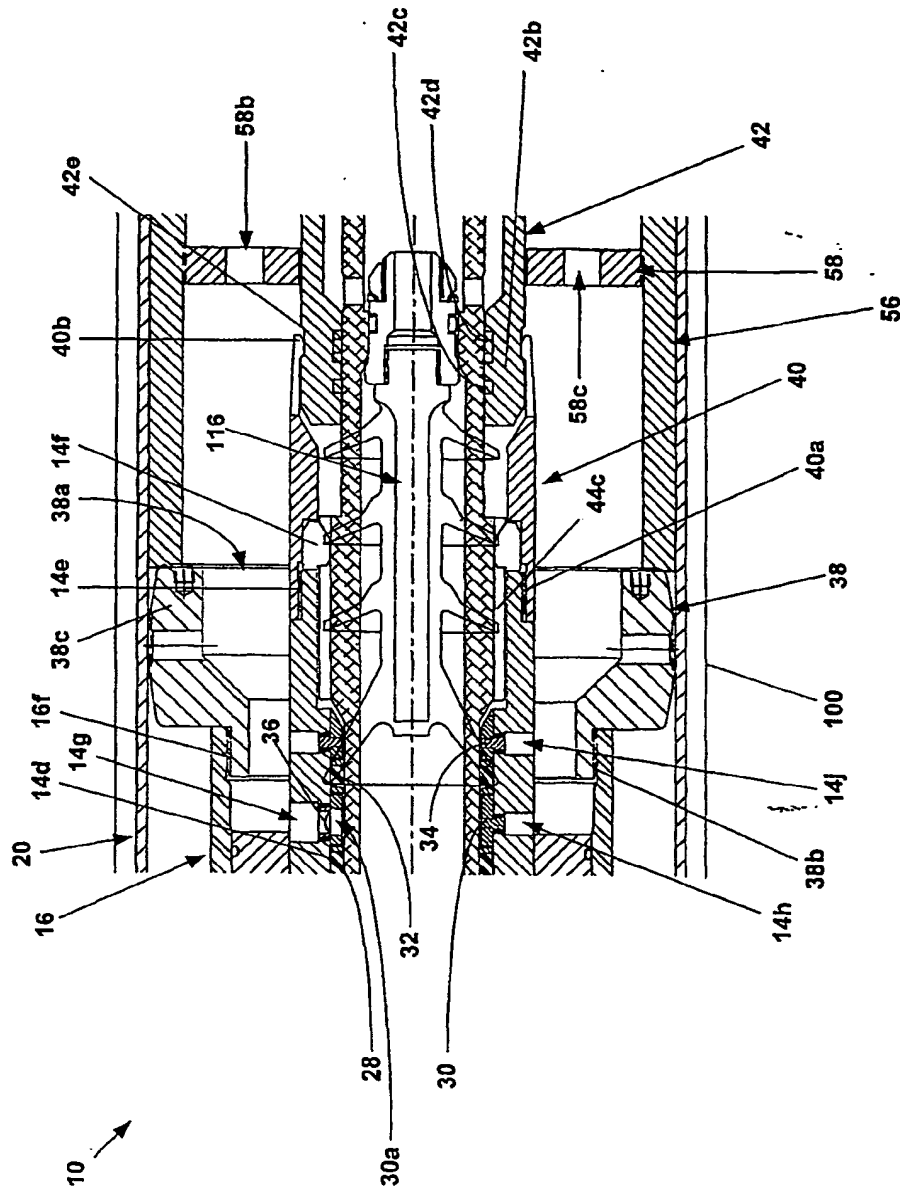


Fig. 8b

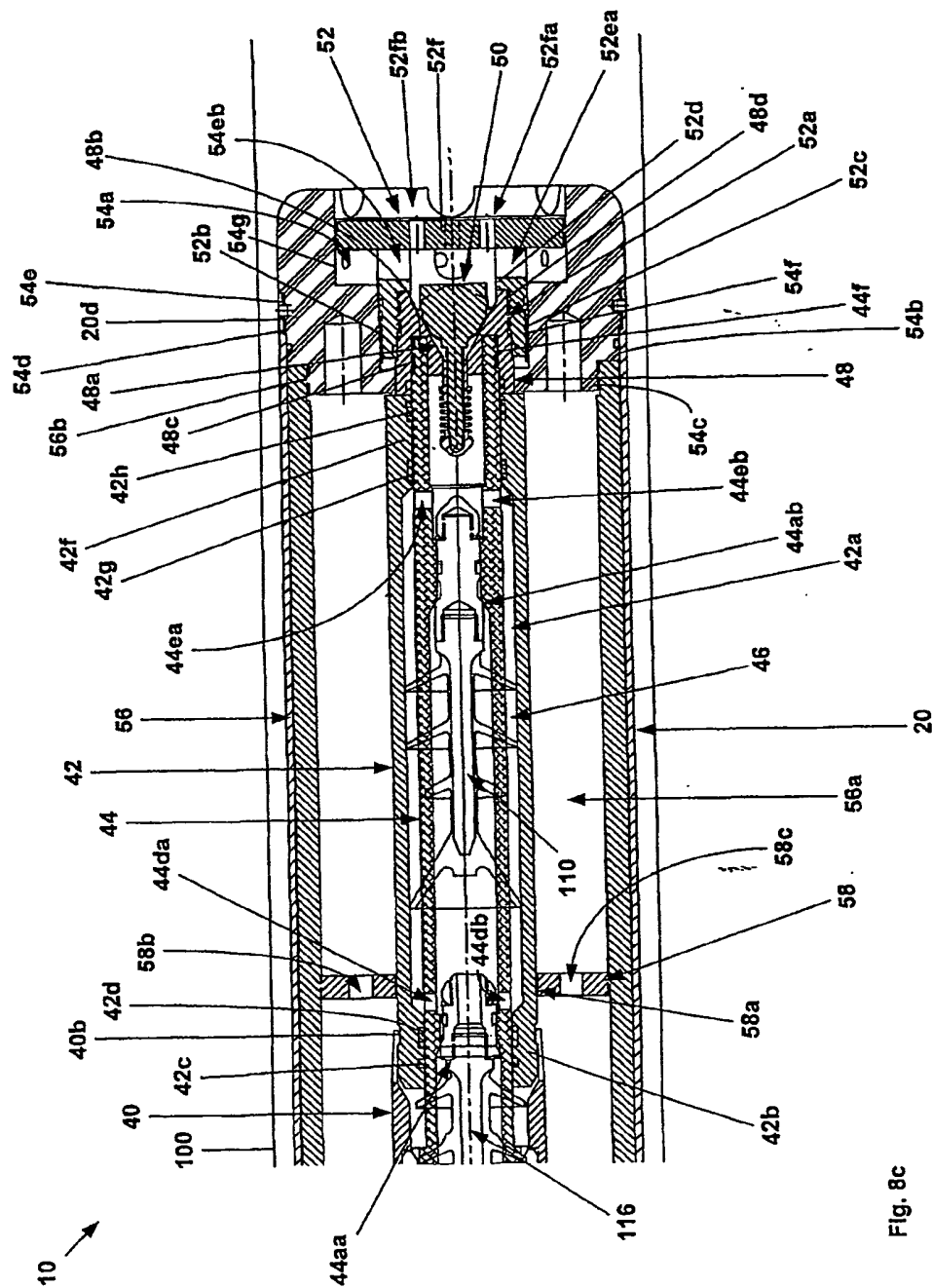


Fig. 8c

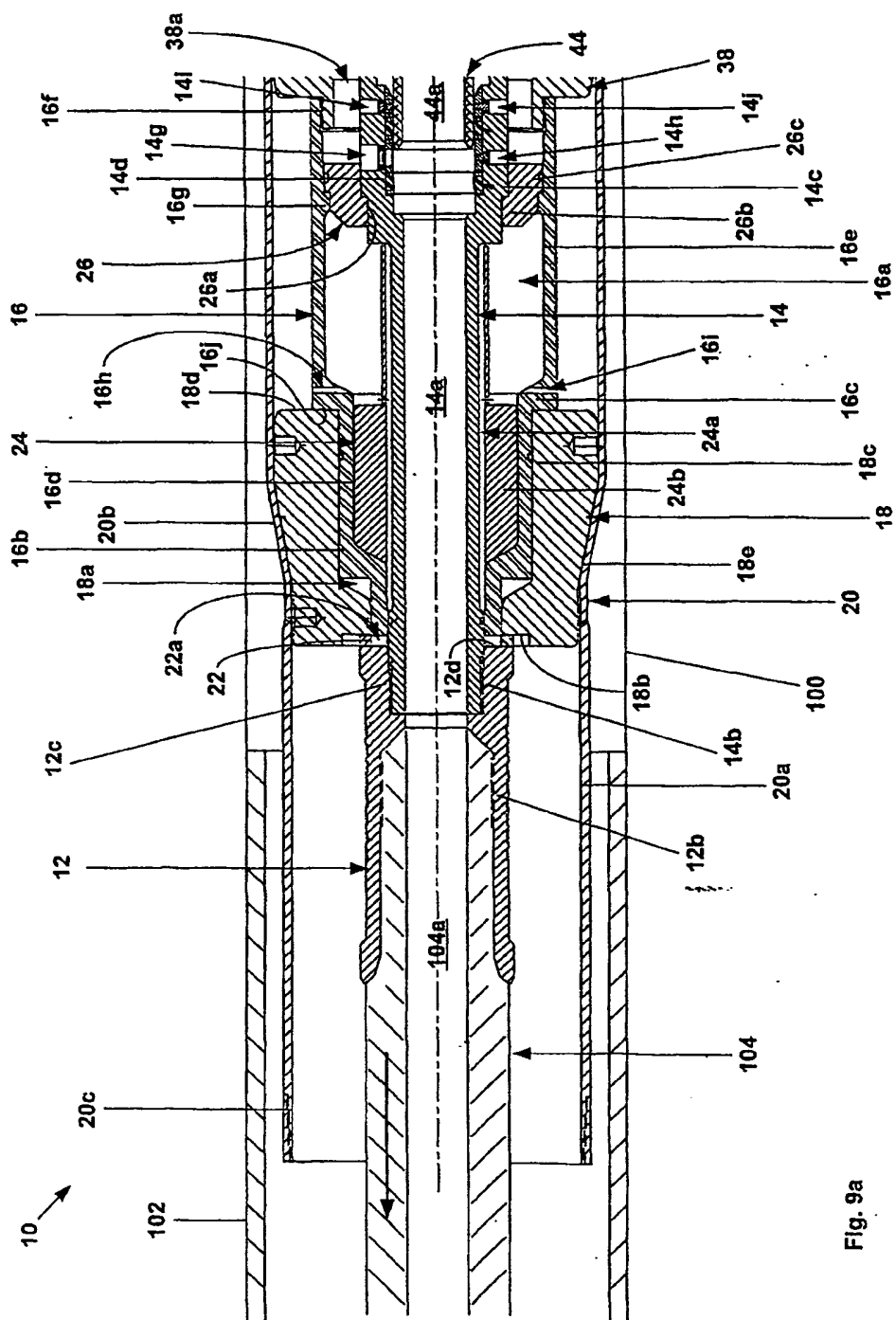
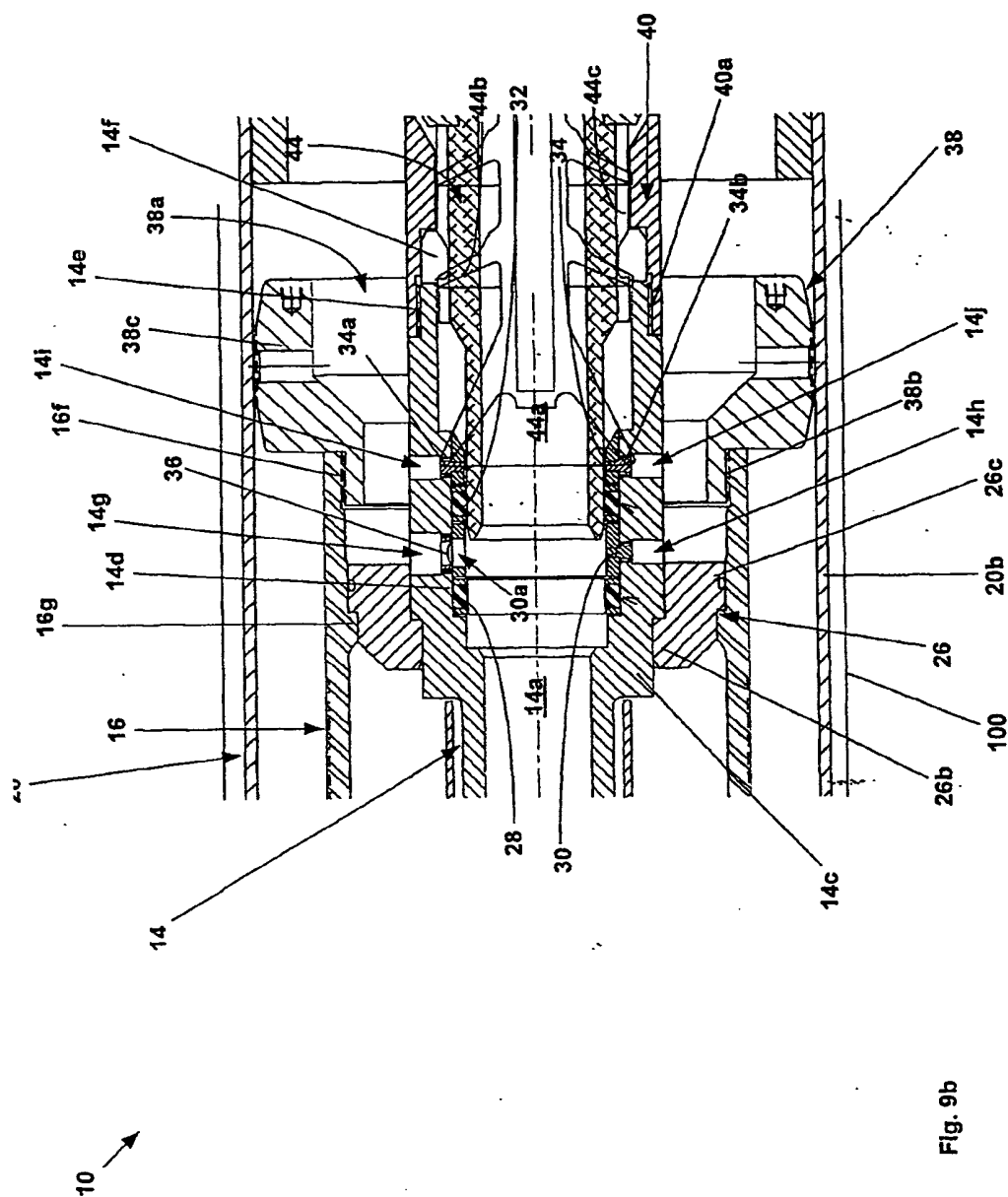


Fig. 9a



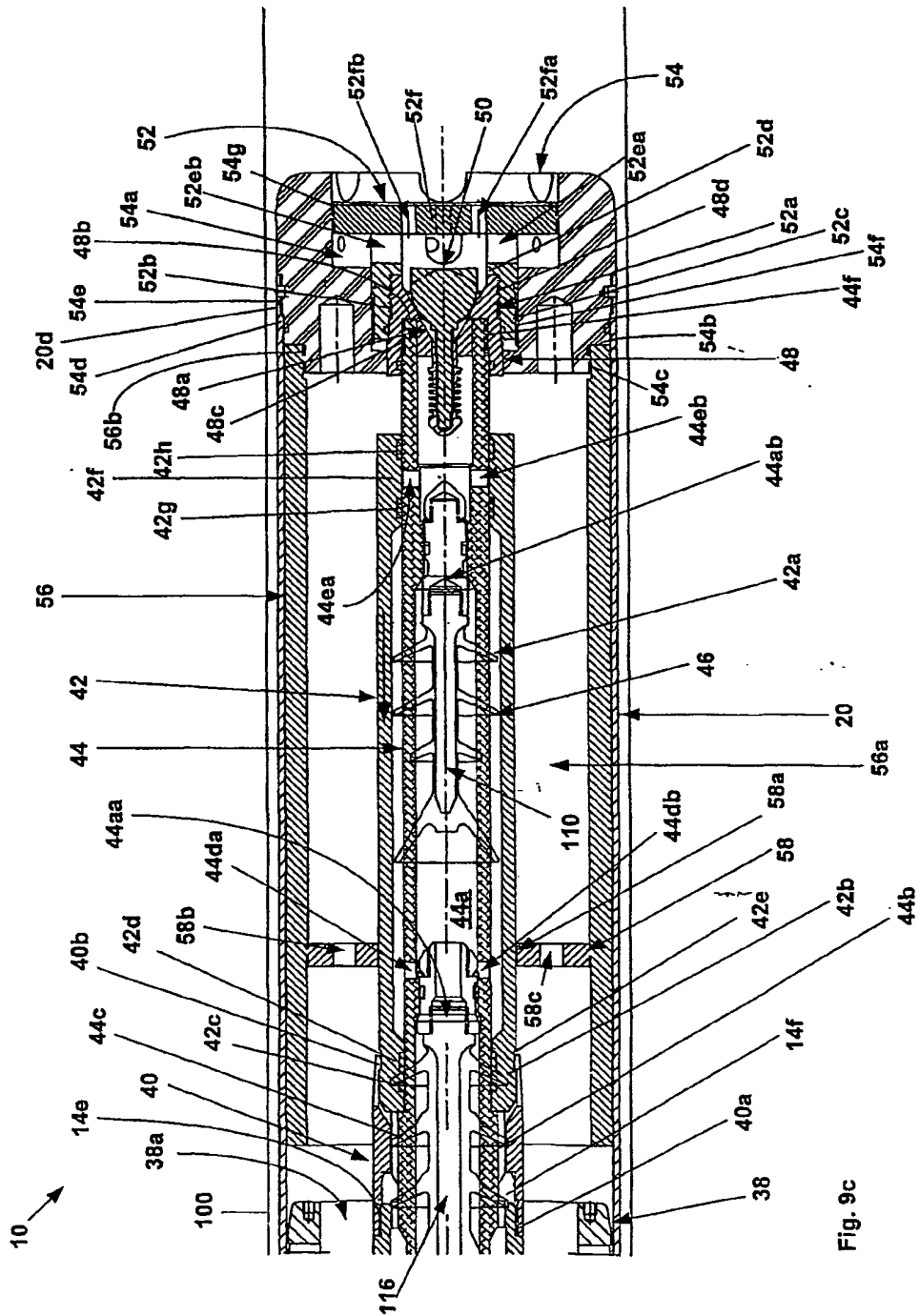


Fig. 9c

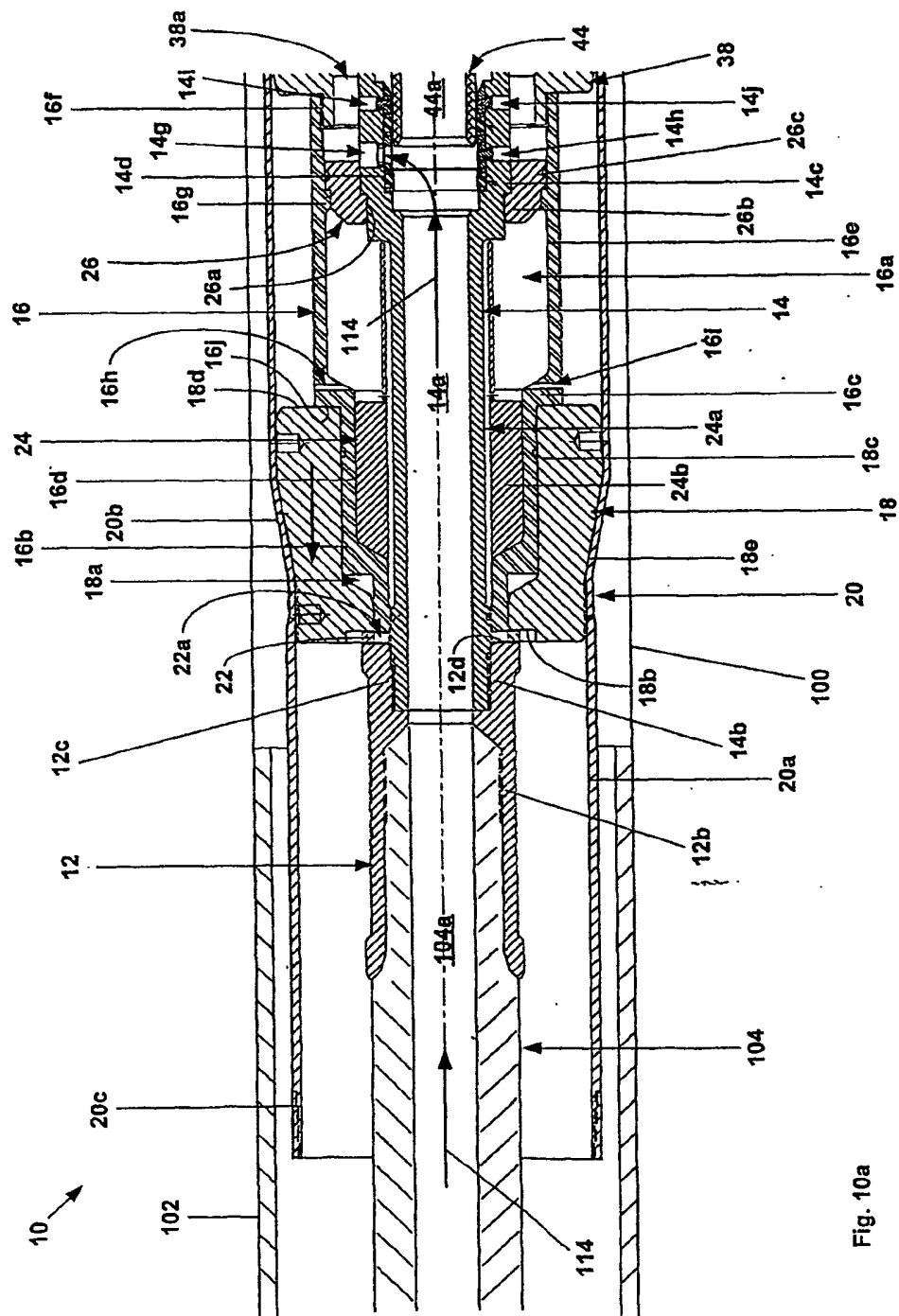
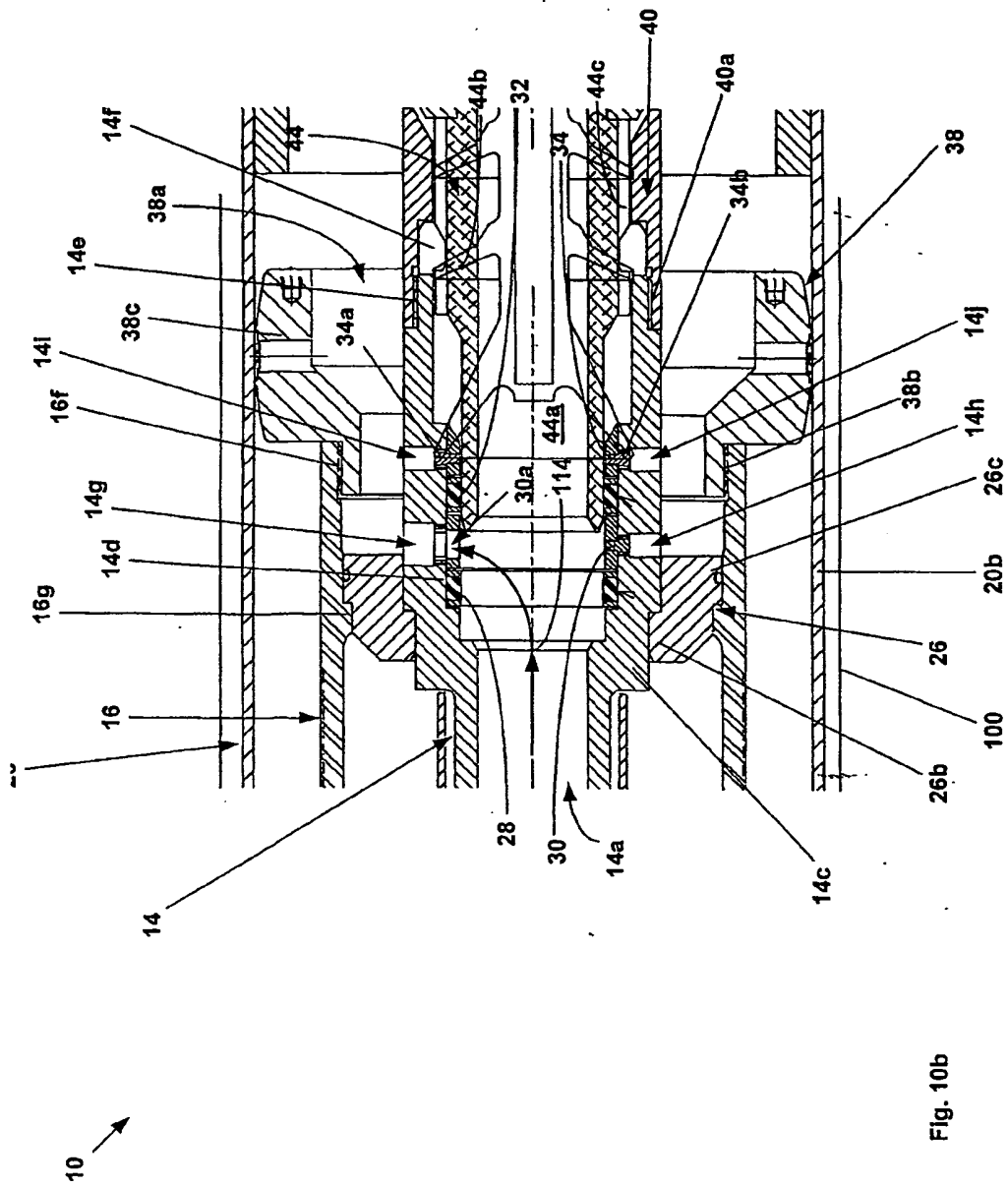


Fig. 10a



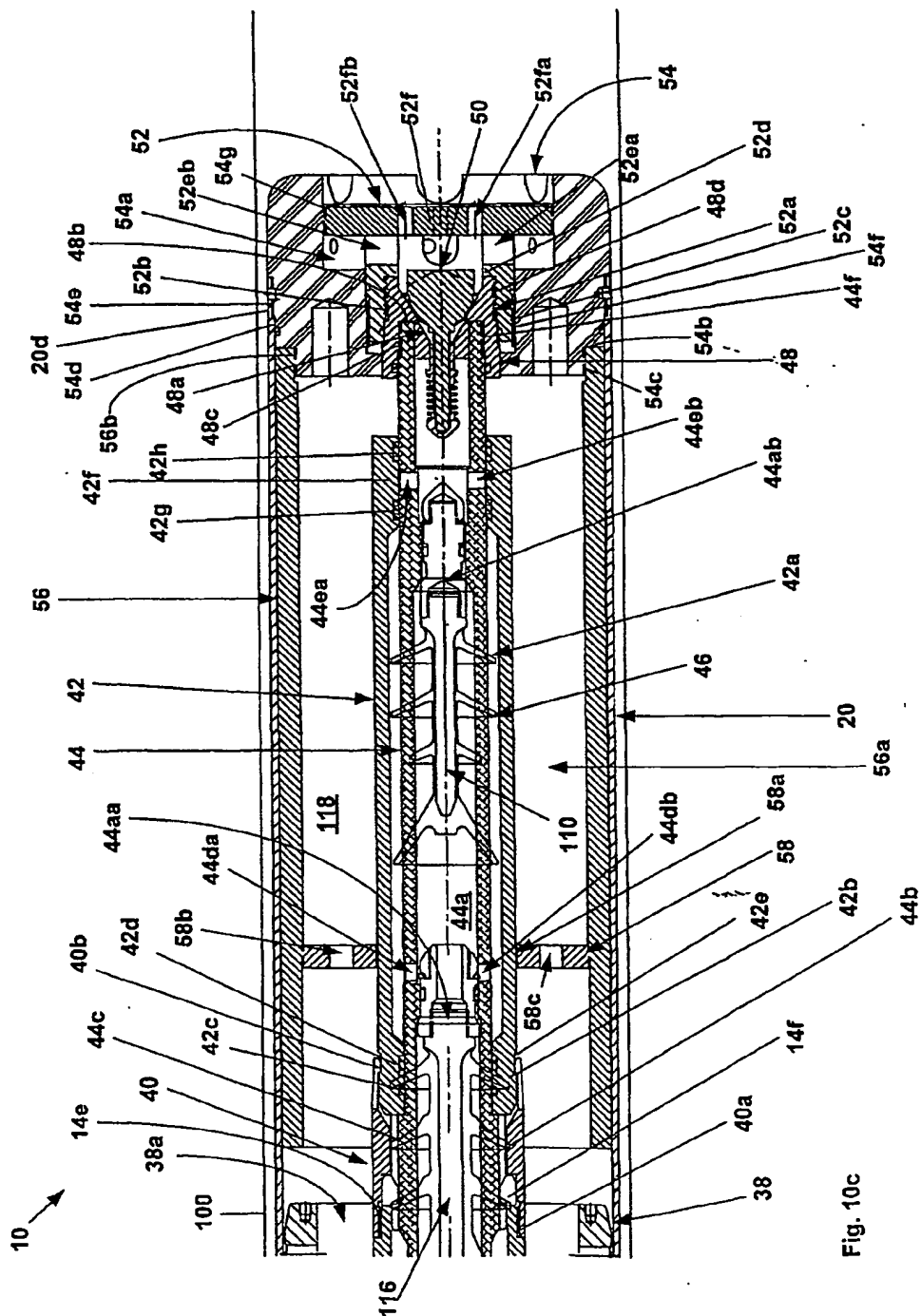


Fig. 10c

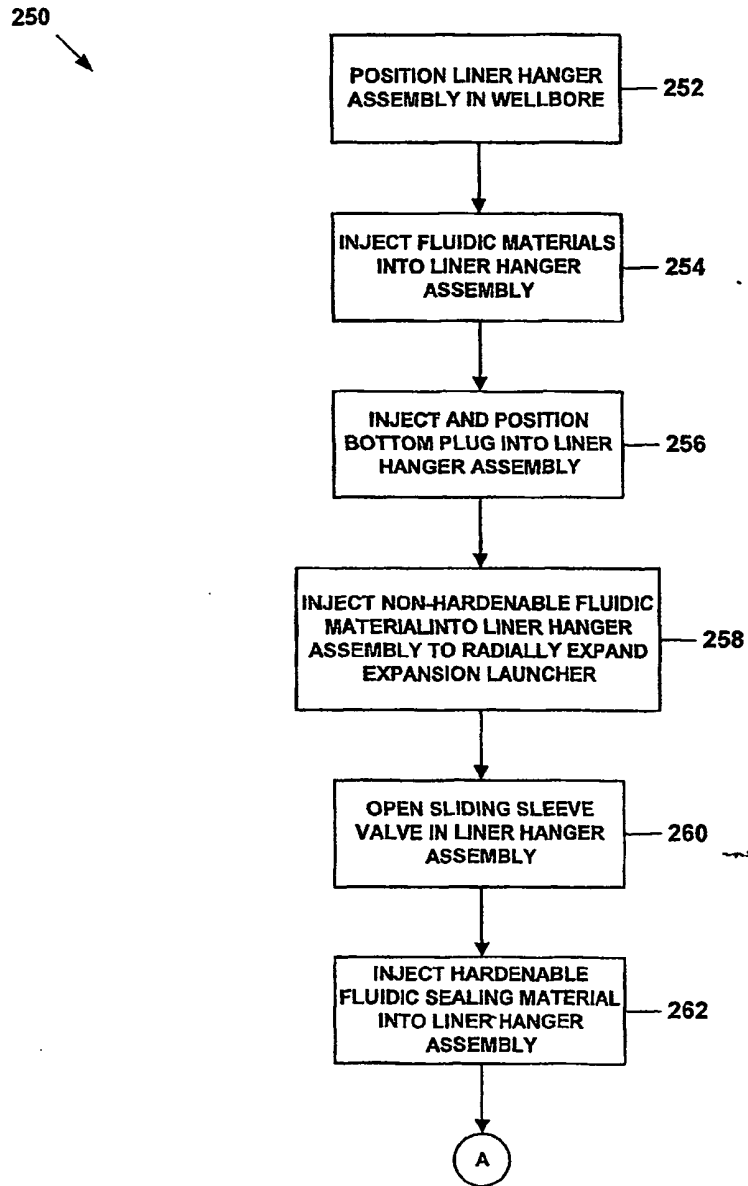


Fig. 11a

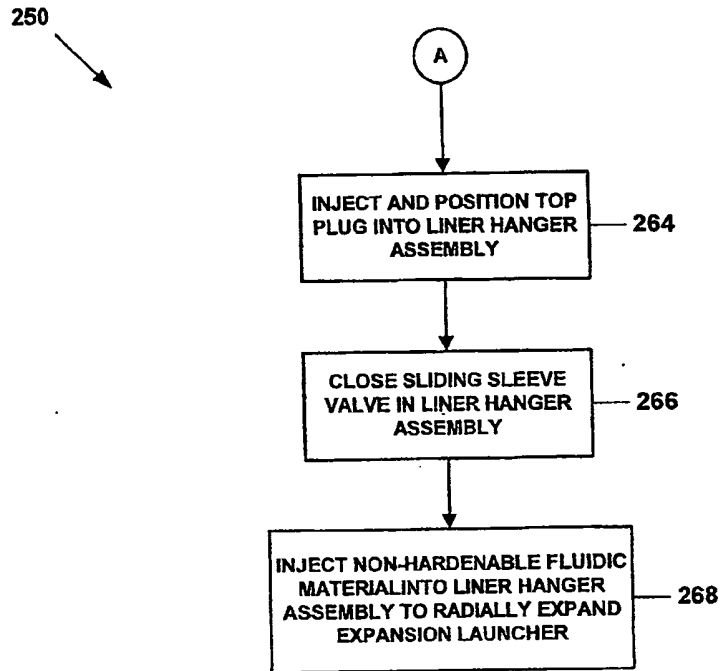


Fig. 11b

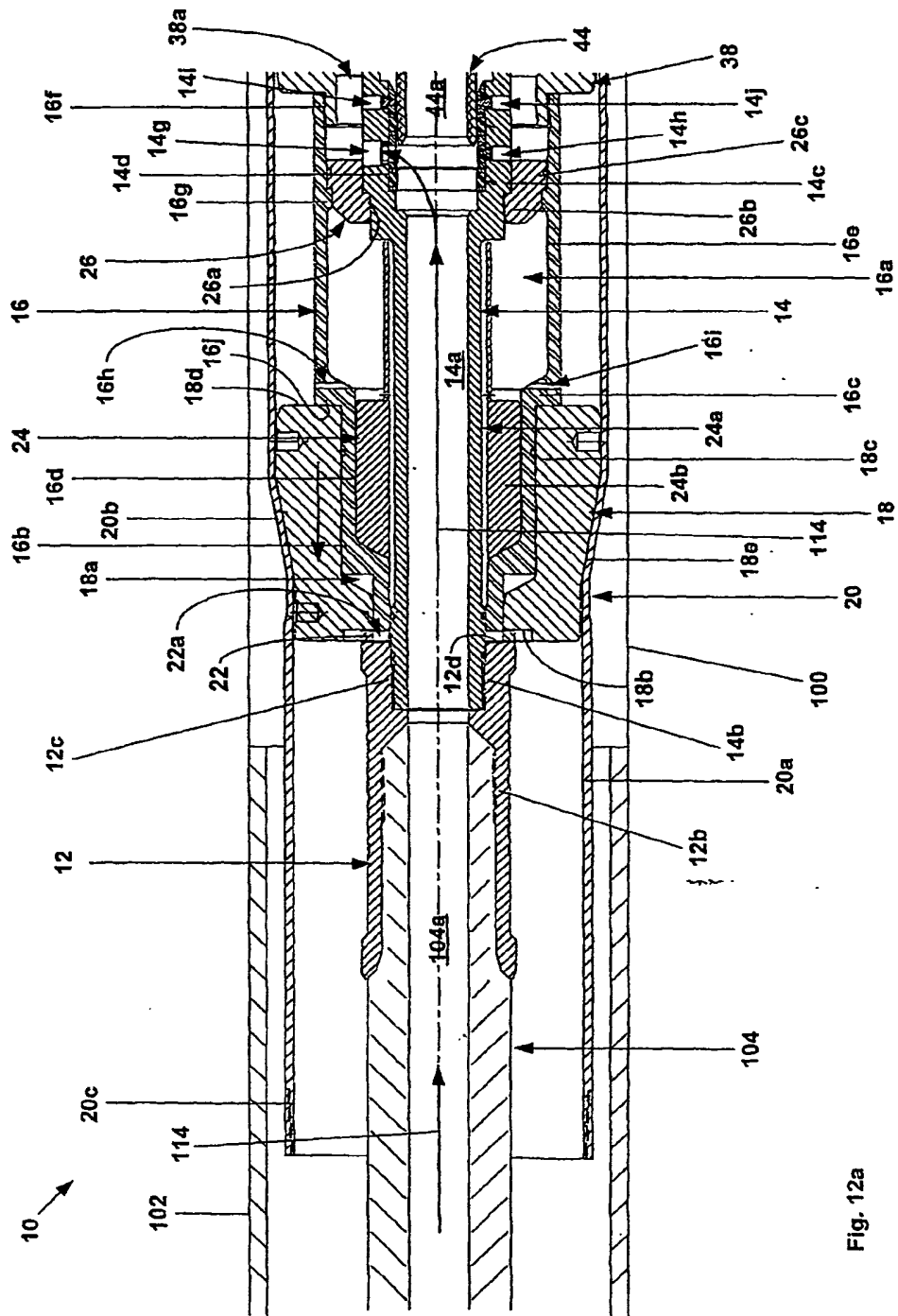


Fig. 12a

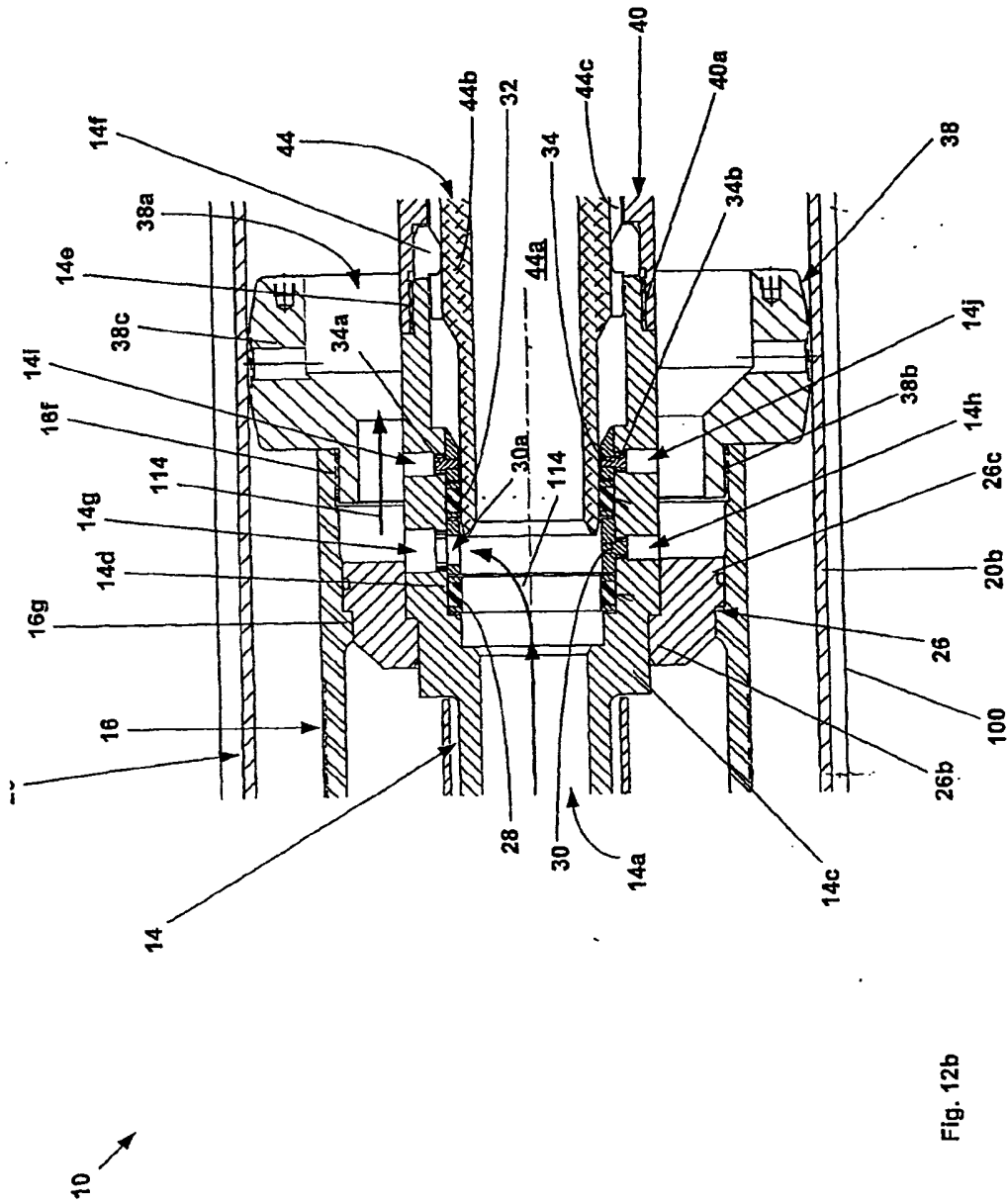
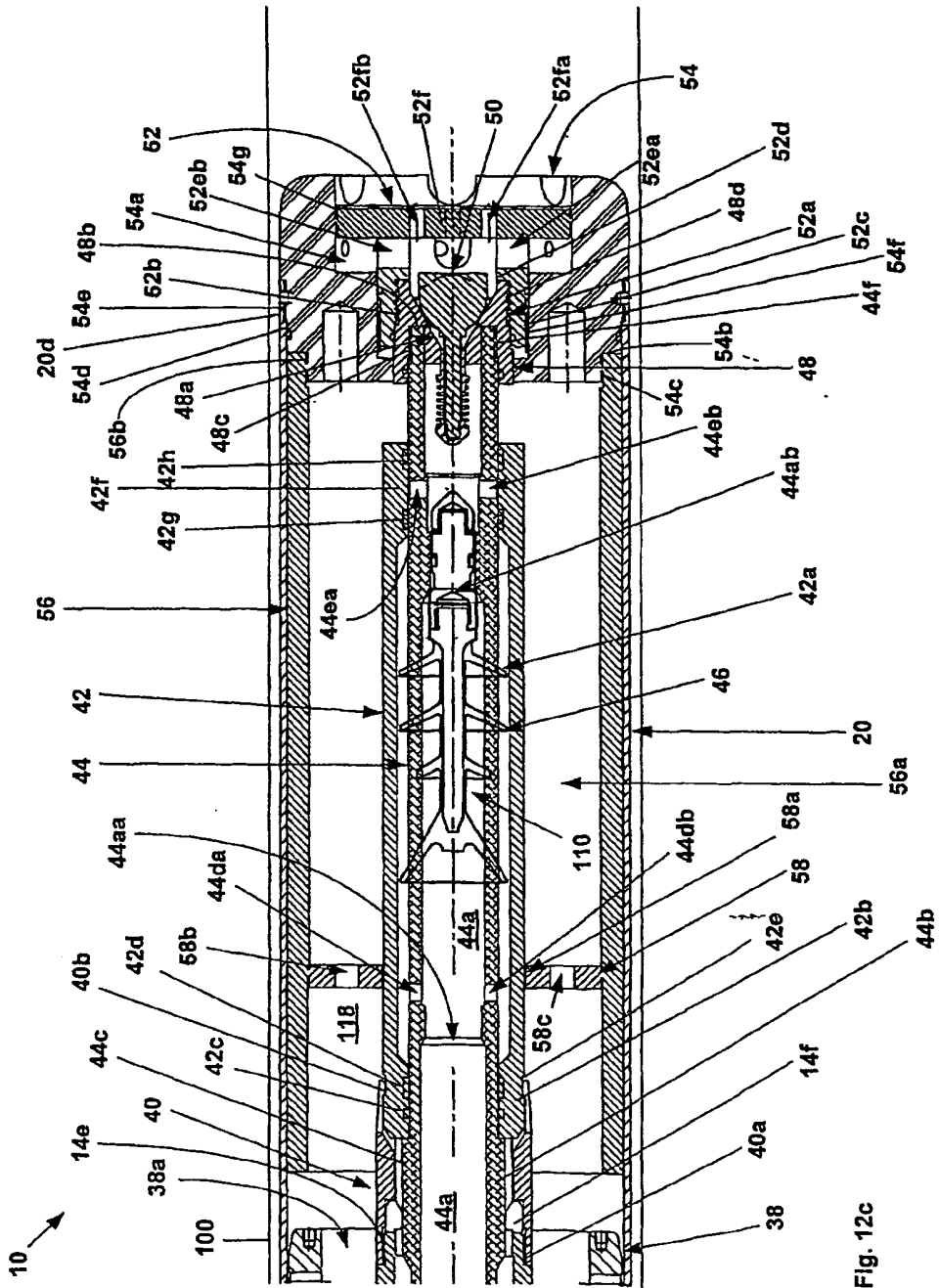


Fig. 12b



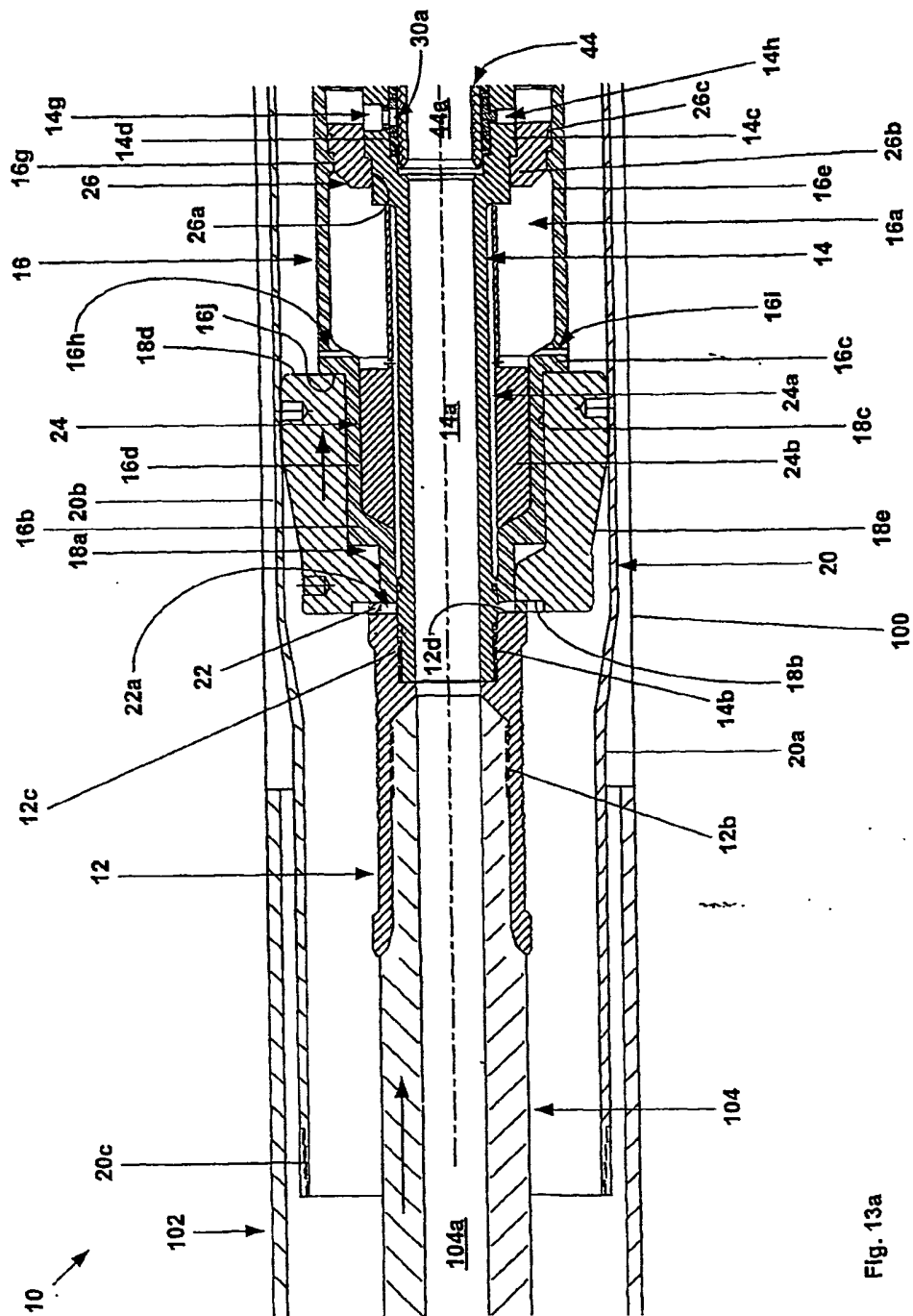


Fig. 13a

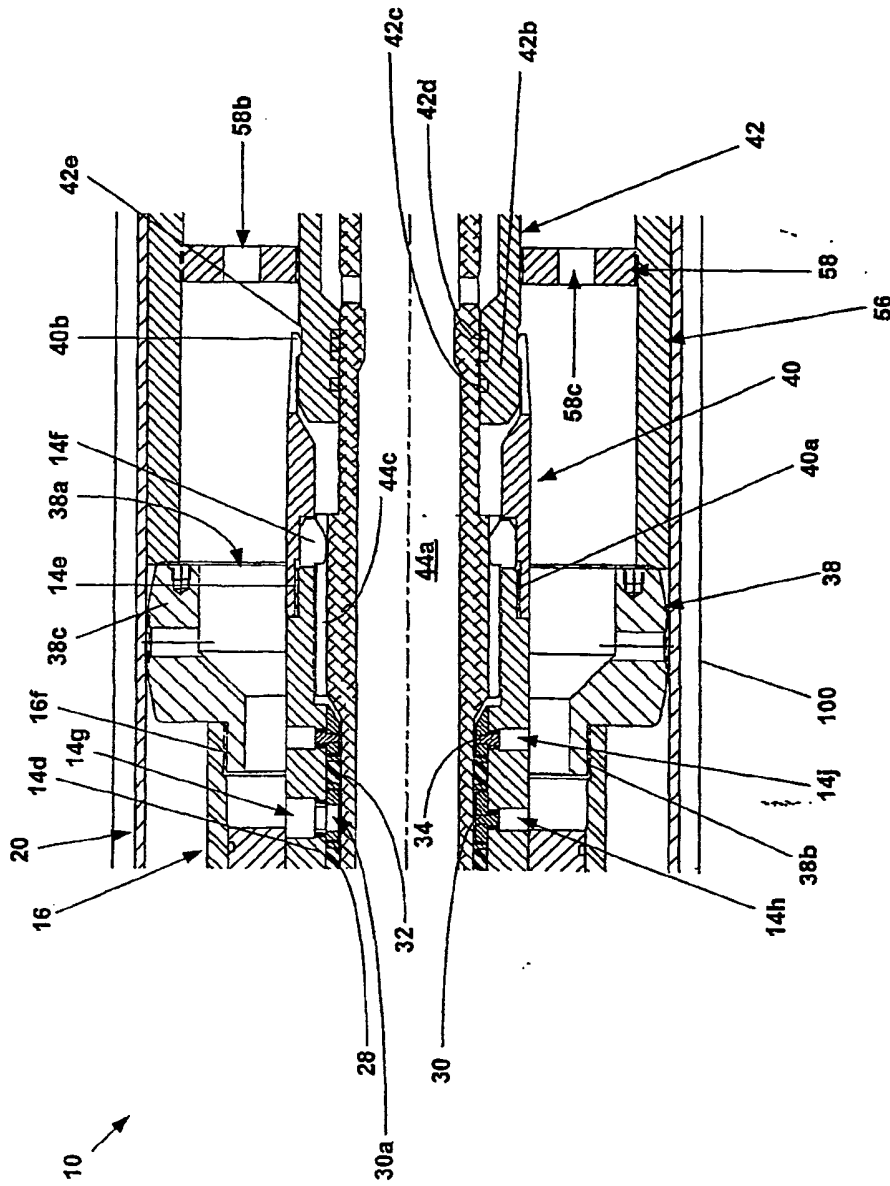


Fig. 13b

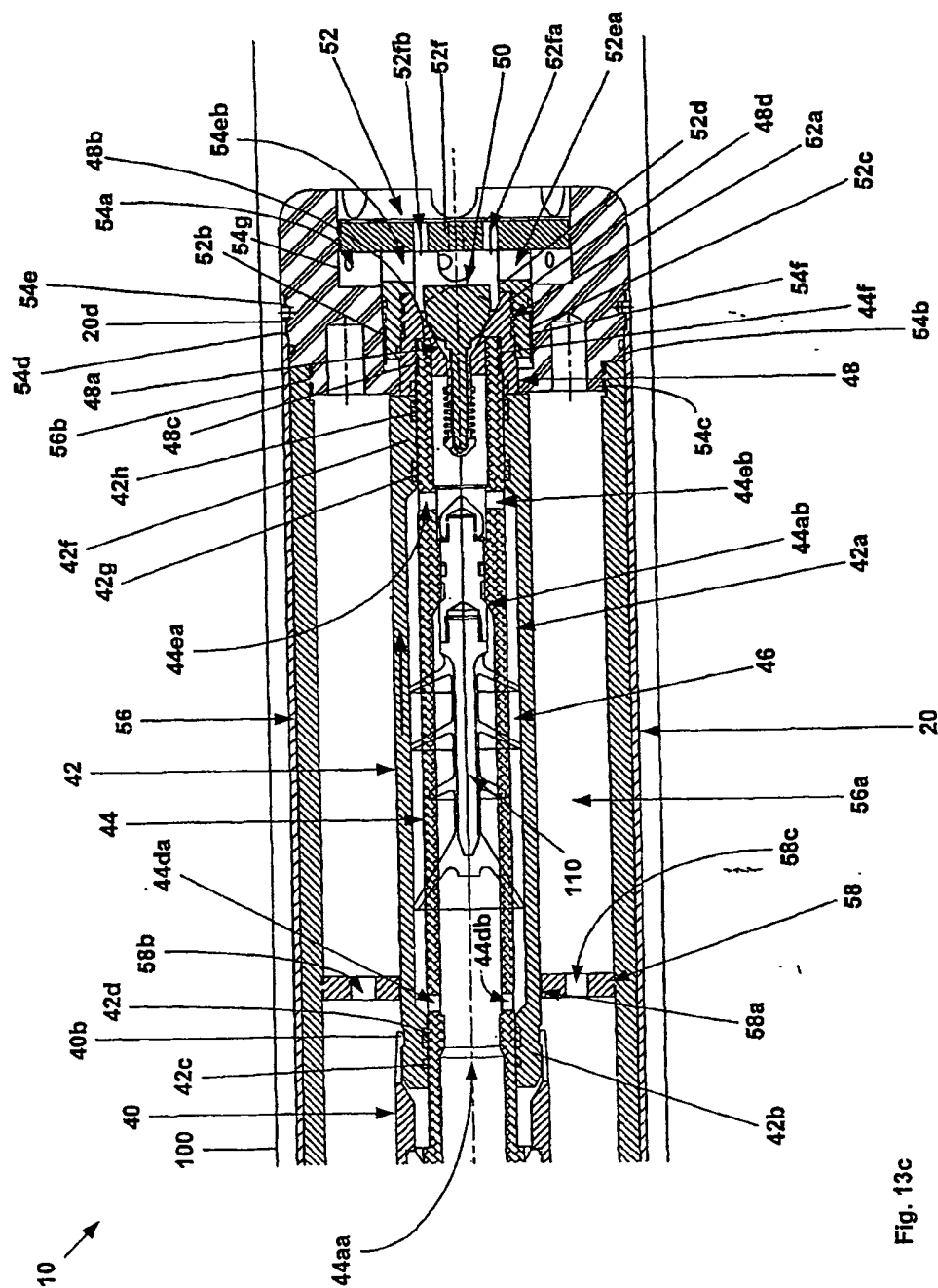


Fig. 13c

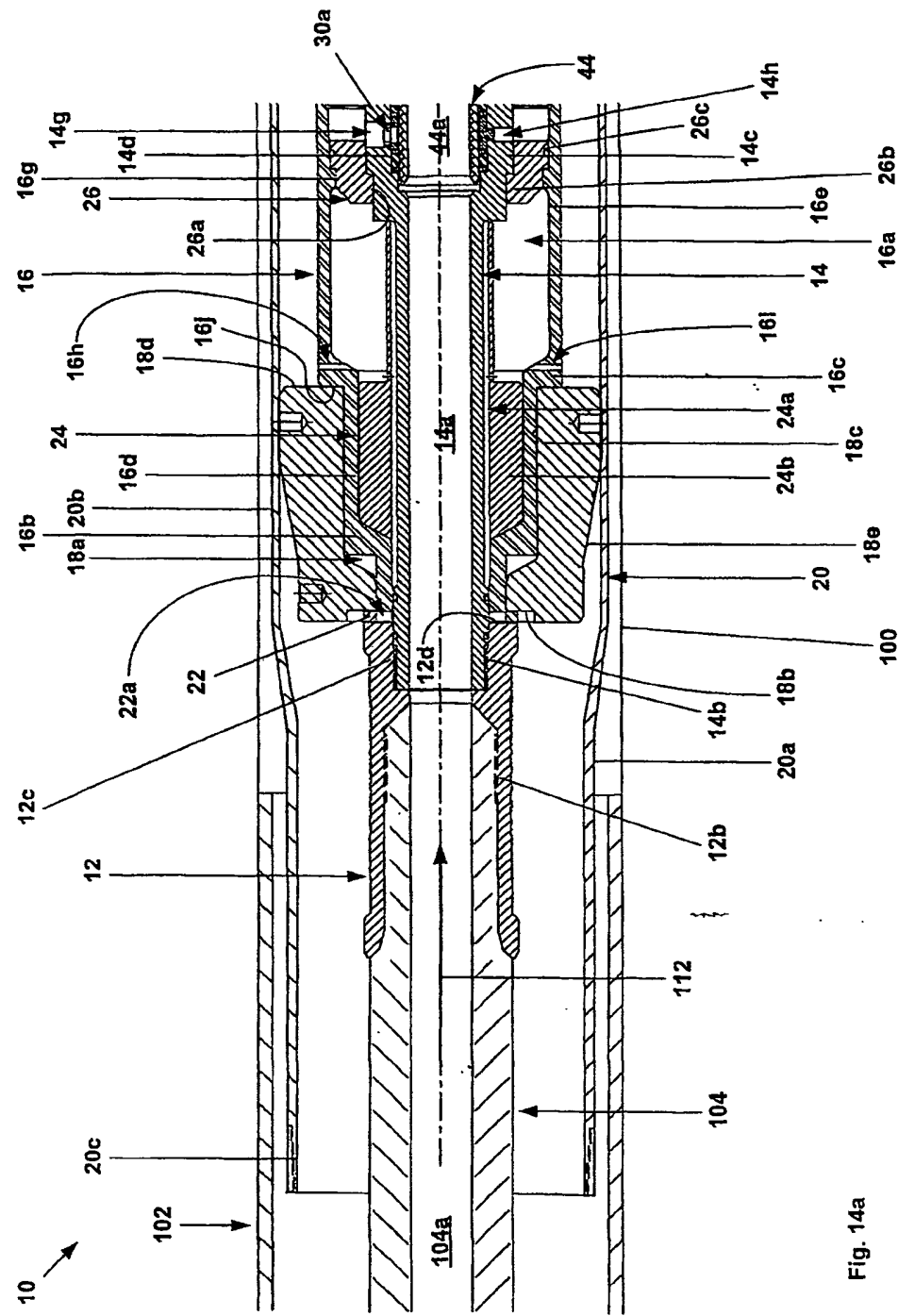


Fig. 14a

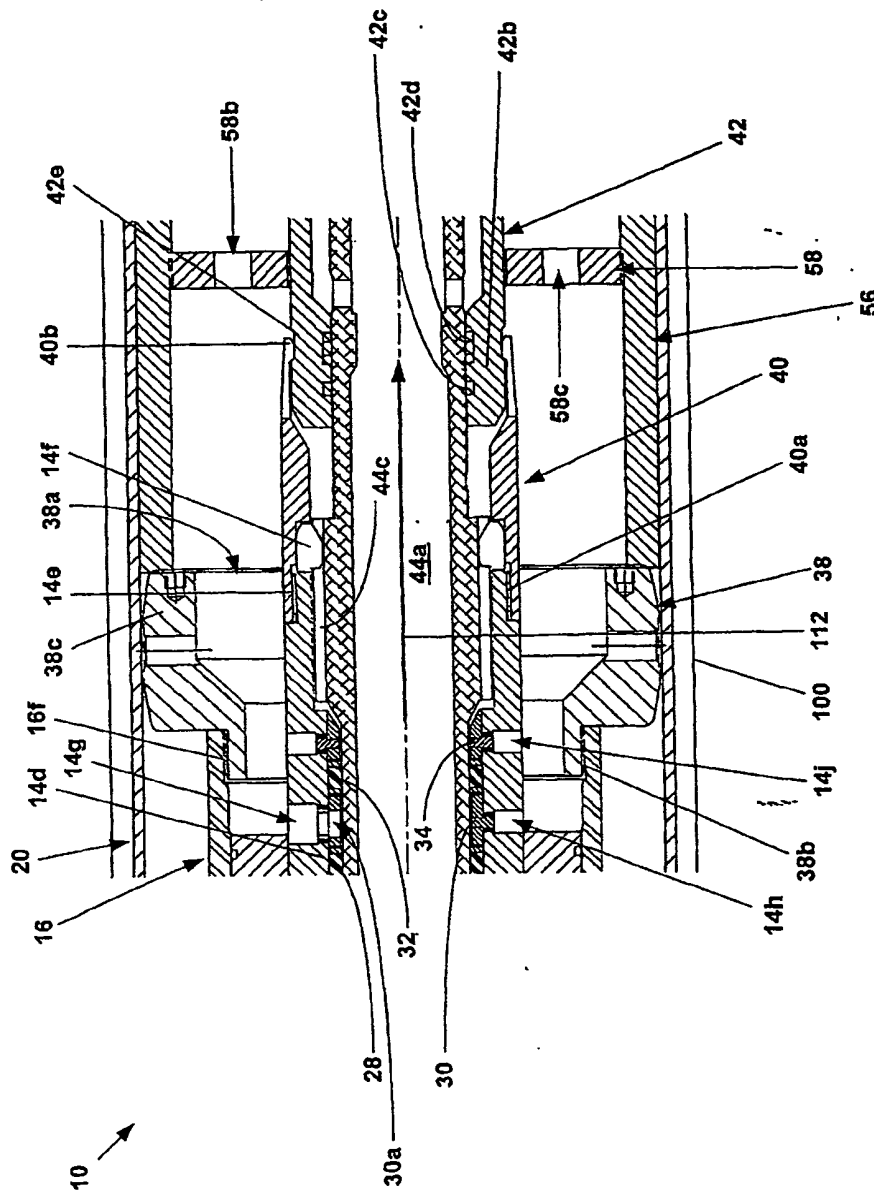


Fig. 14b

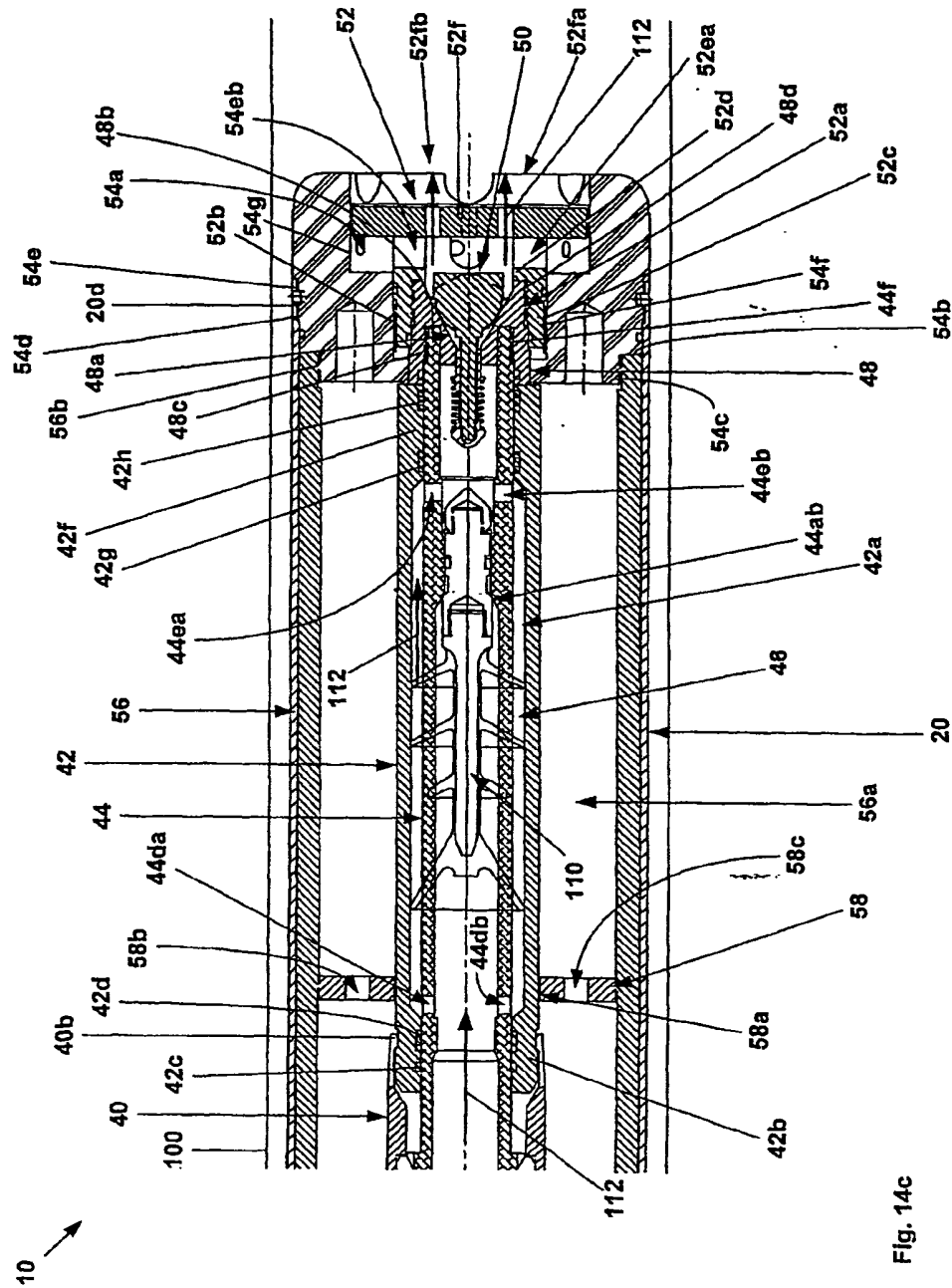


Fig. 14c

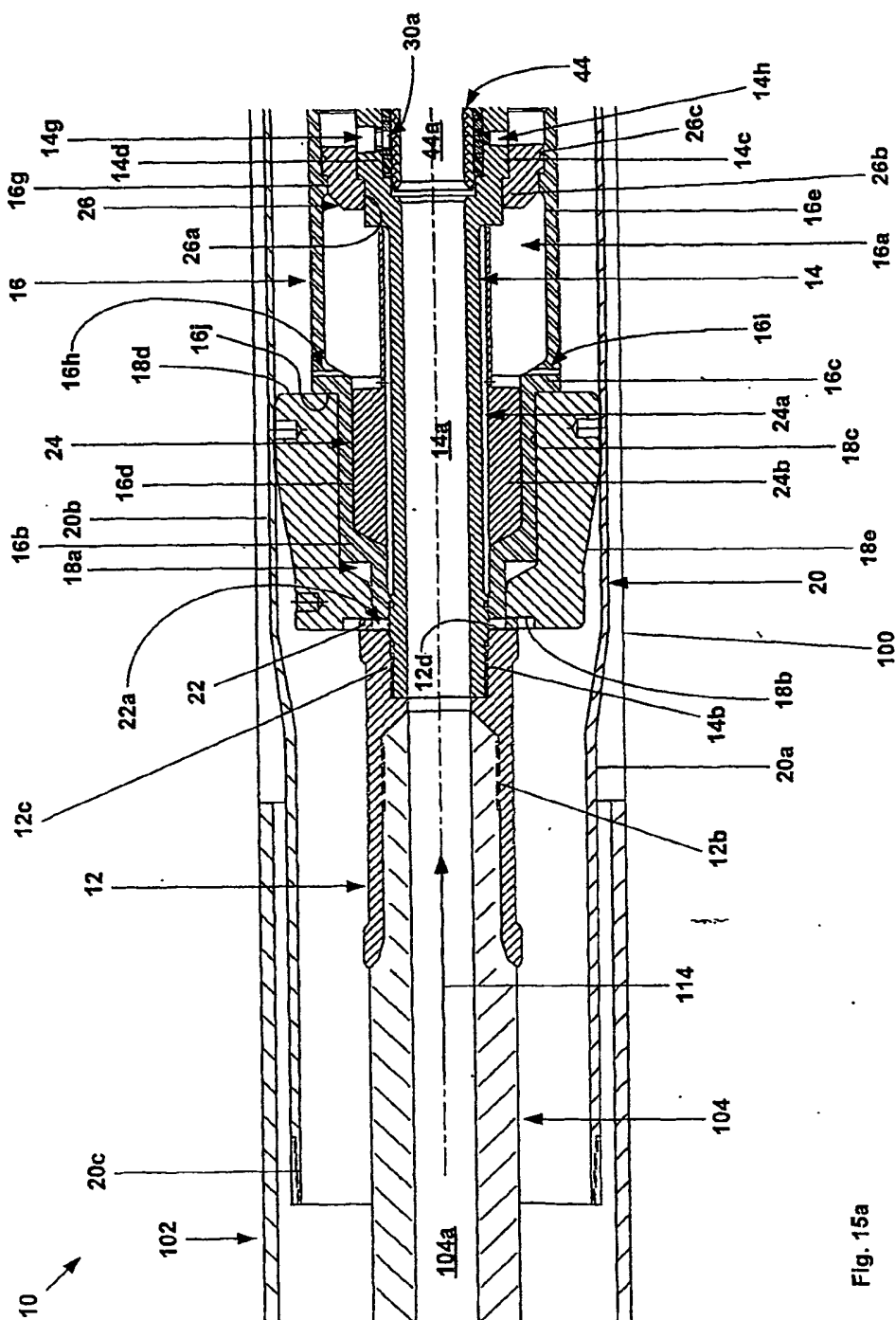


Fig. 15a

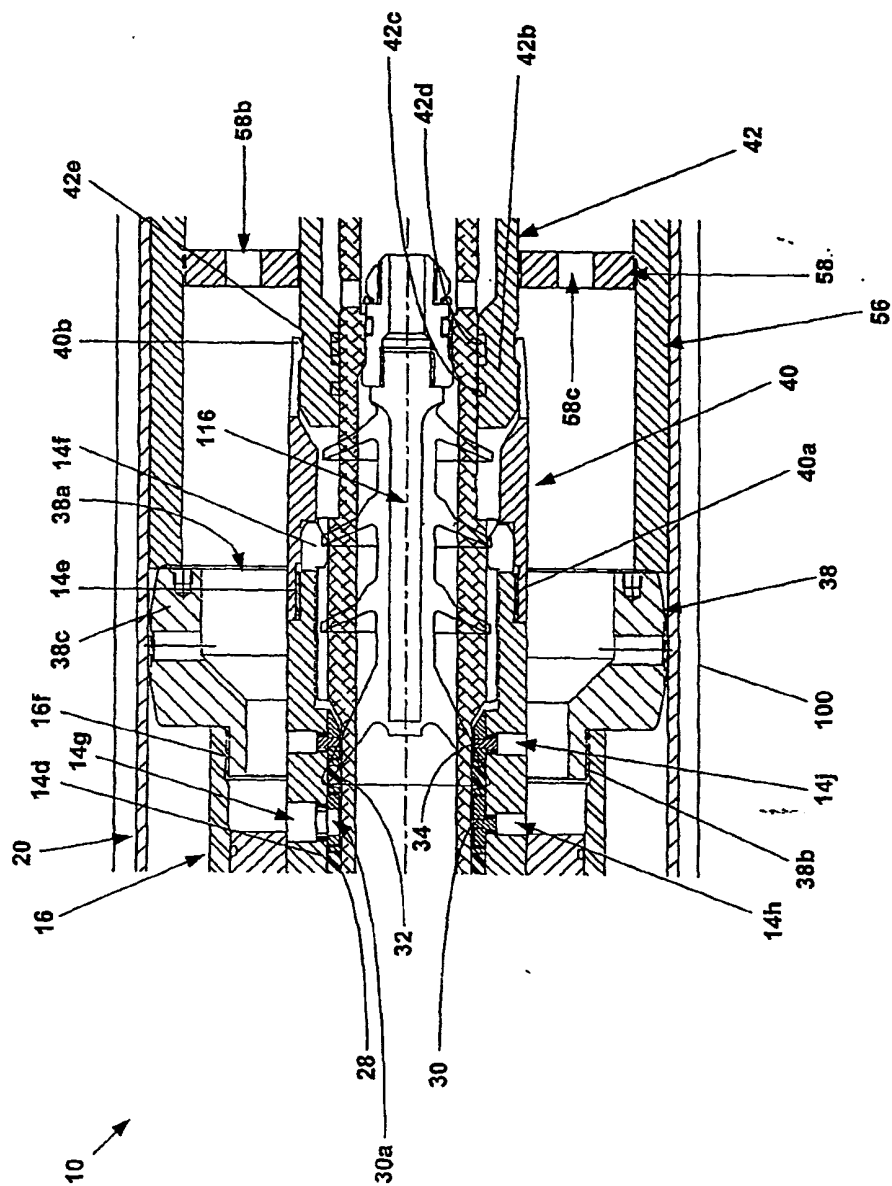


Fig. 15b

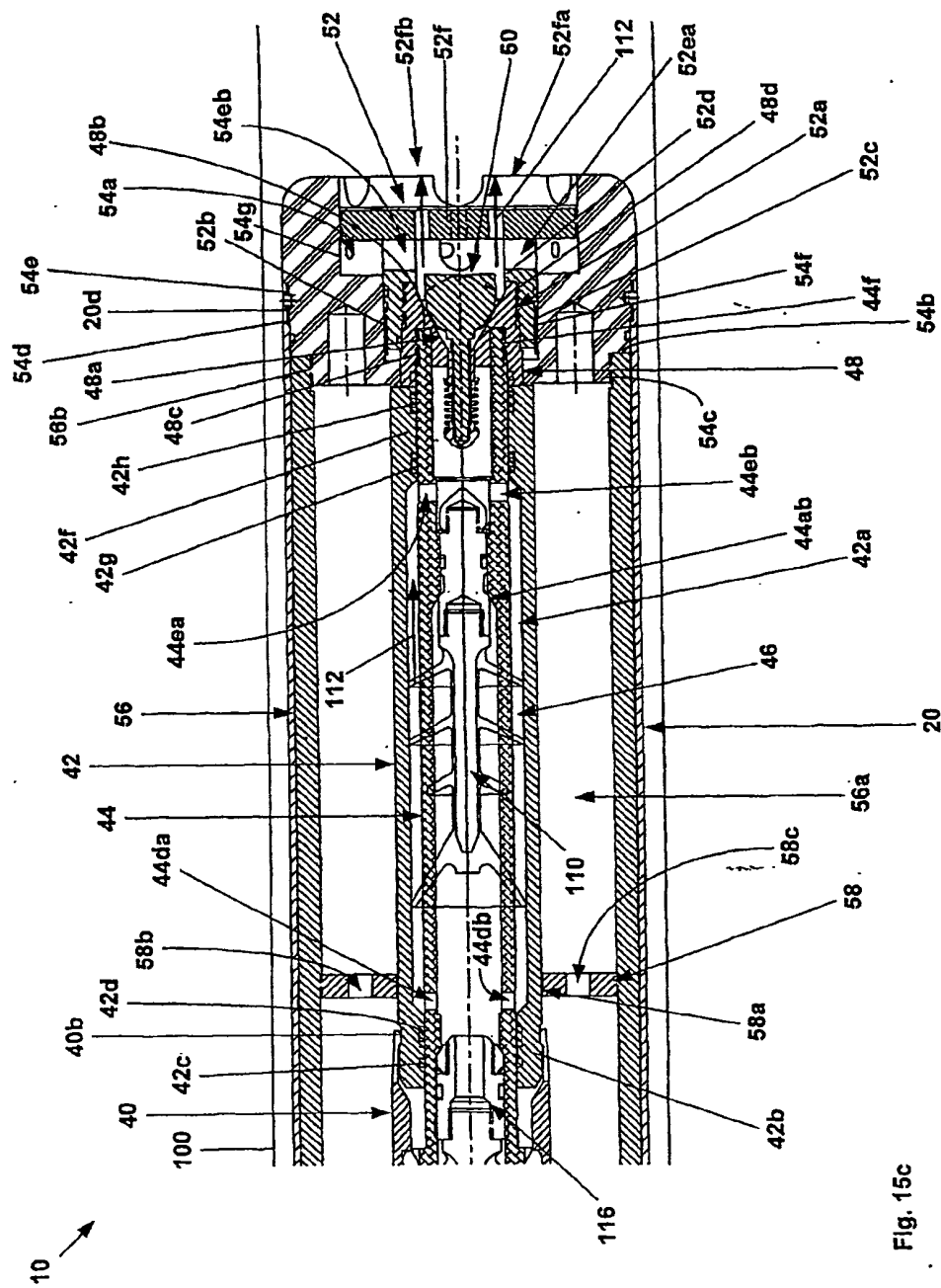


Fig. 15c

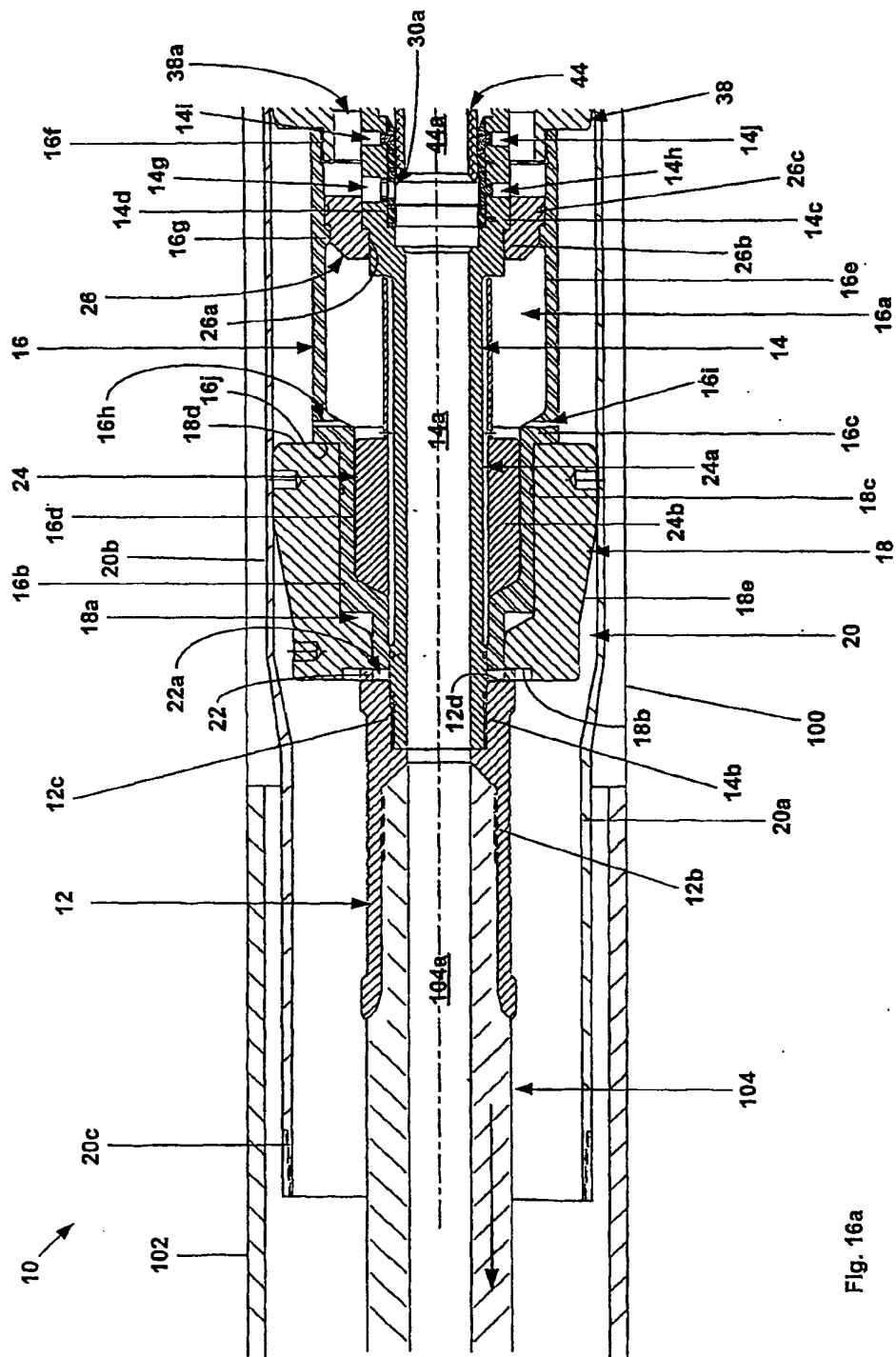


Fig. 16a

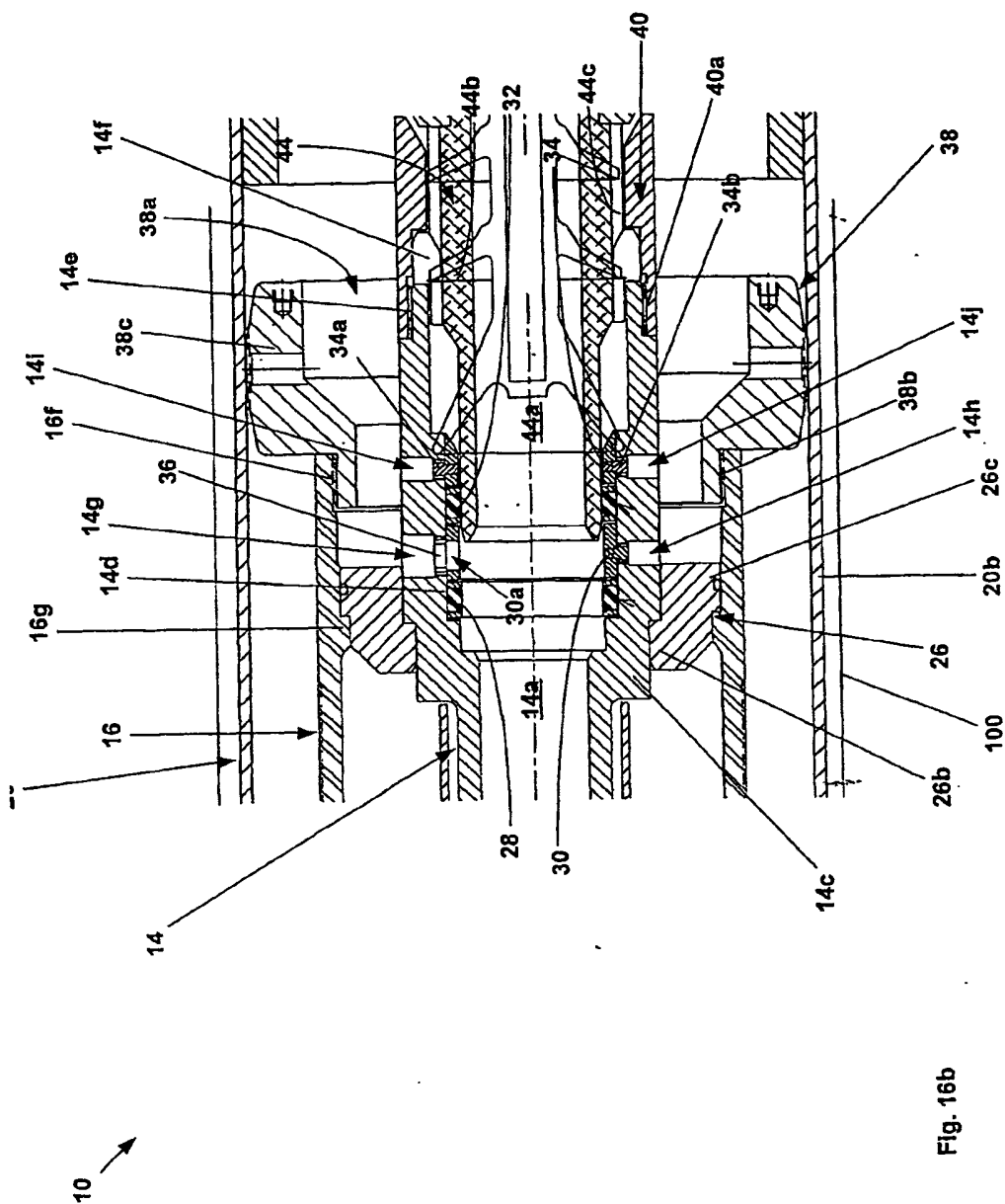


Fig. 16b

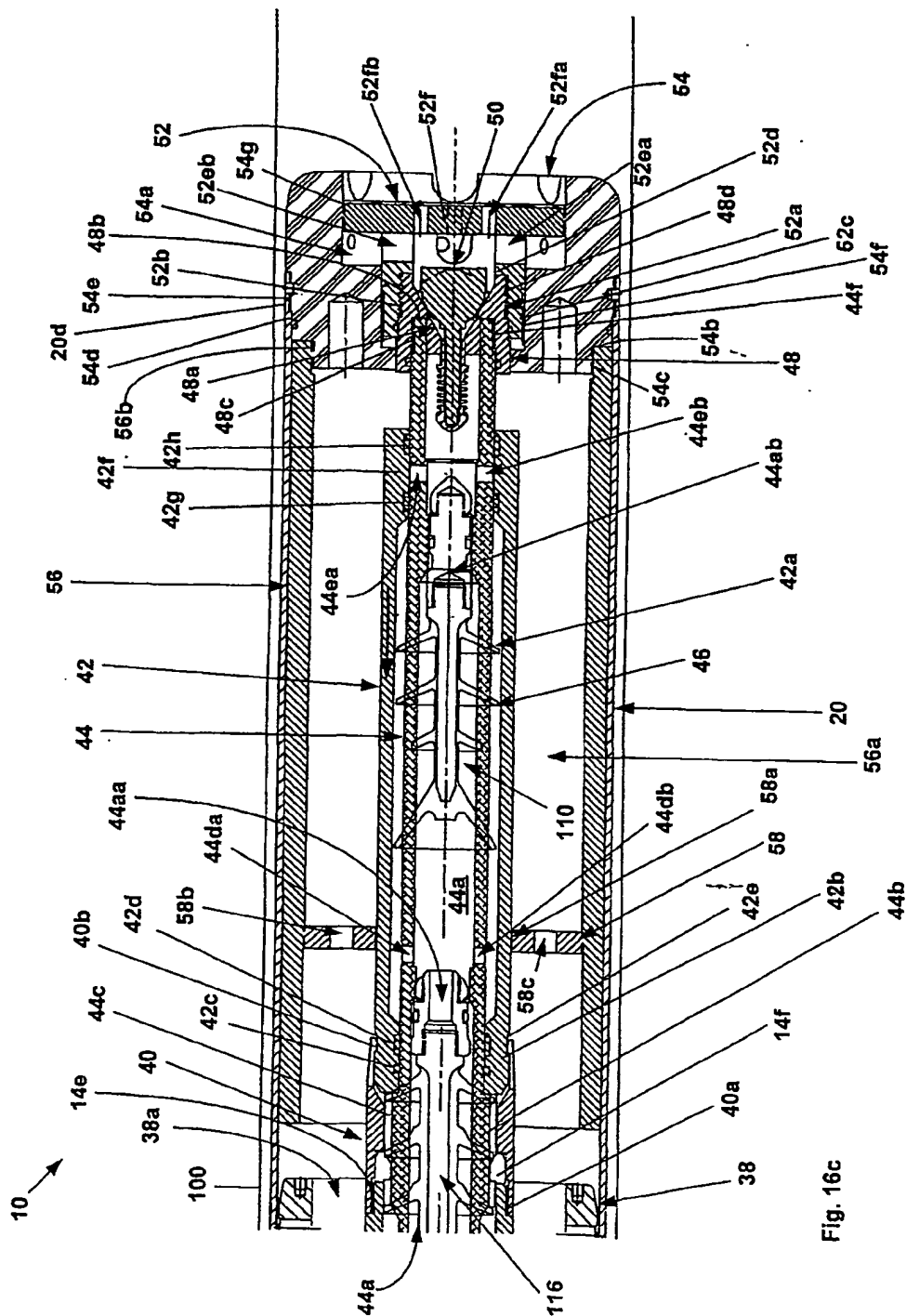


Fig. 16c

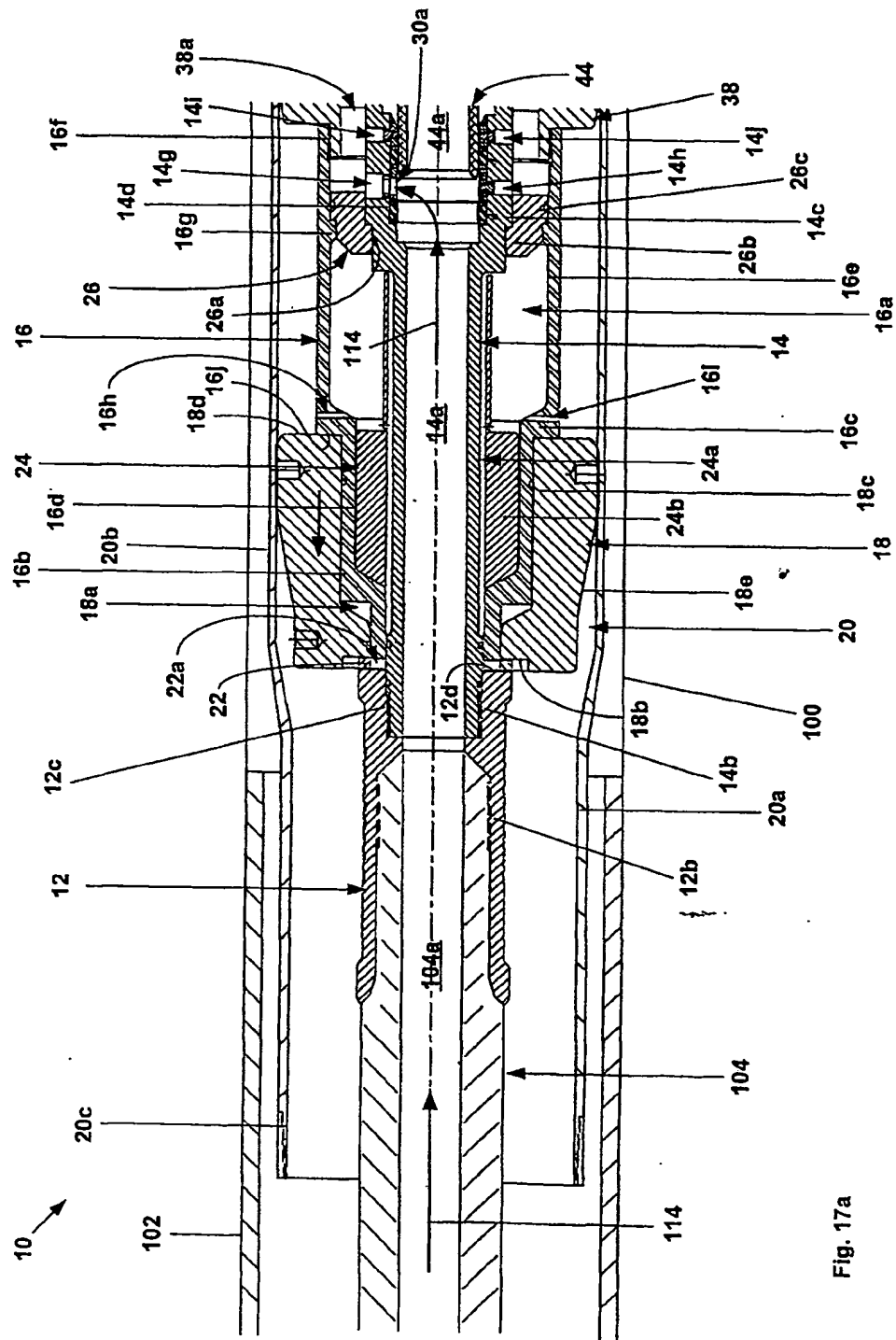


Fig. 17a

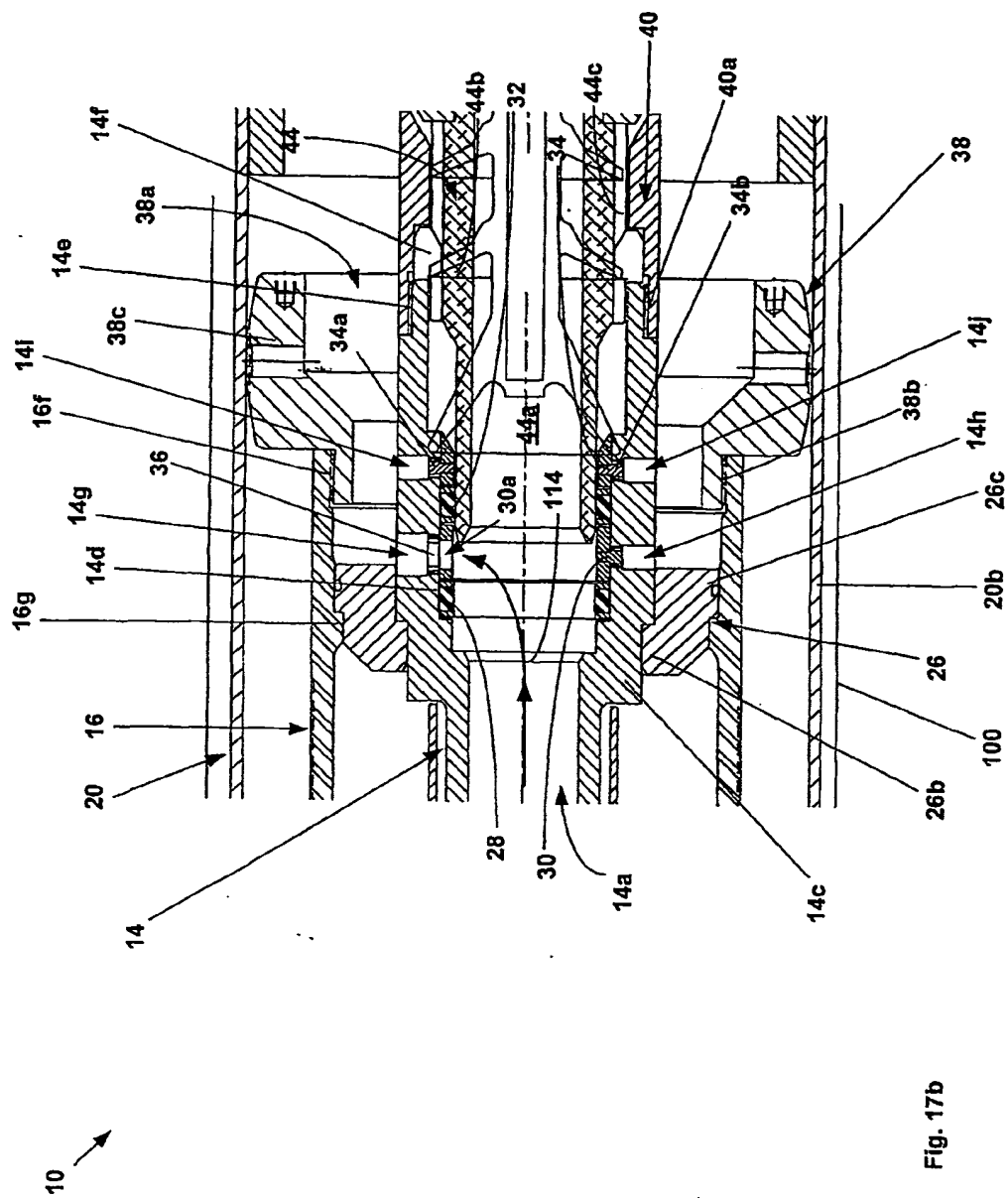


Fig. 17b

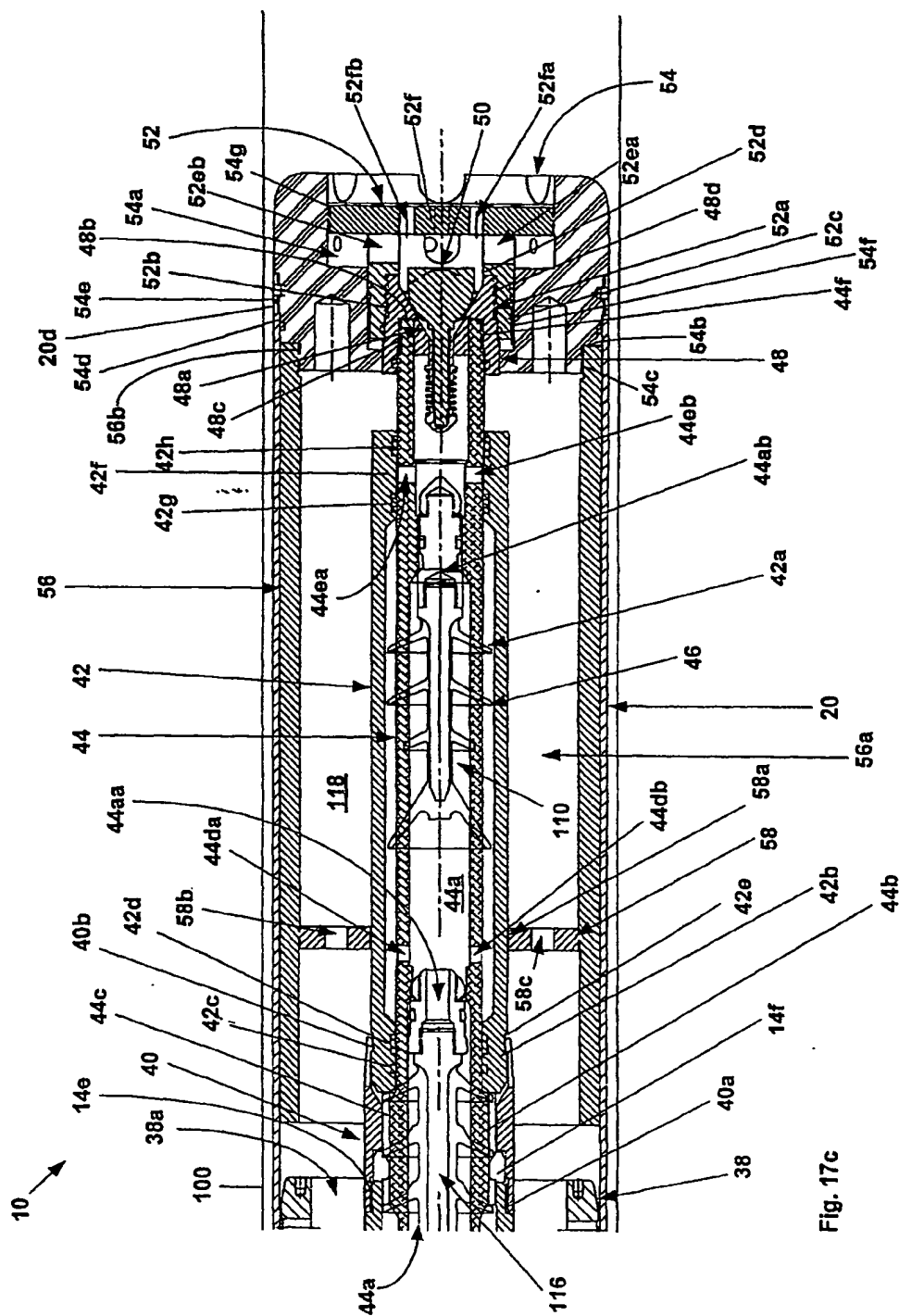


Fig. 17c

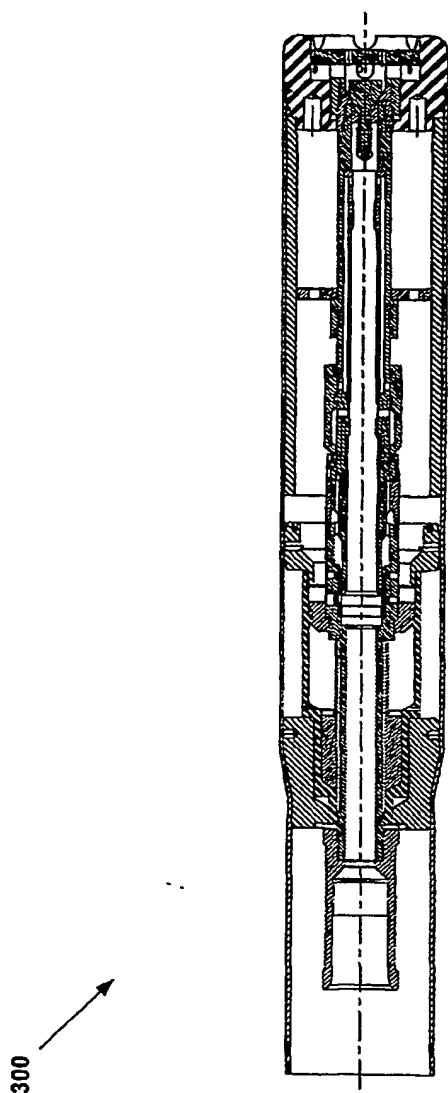


Fig. 18

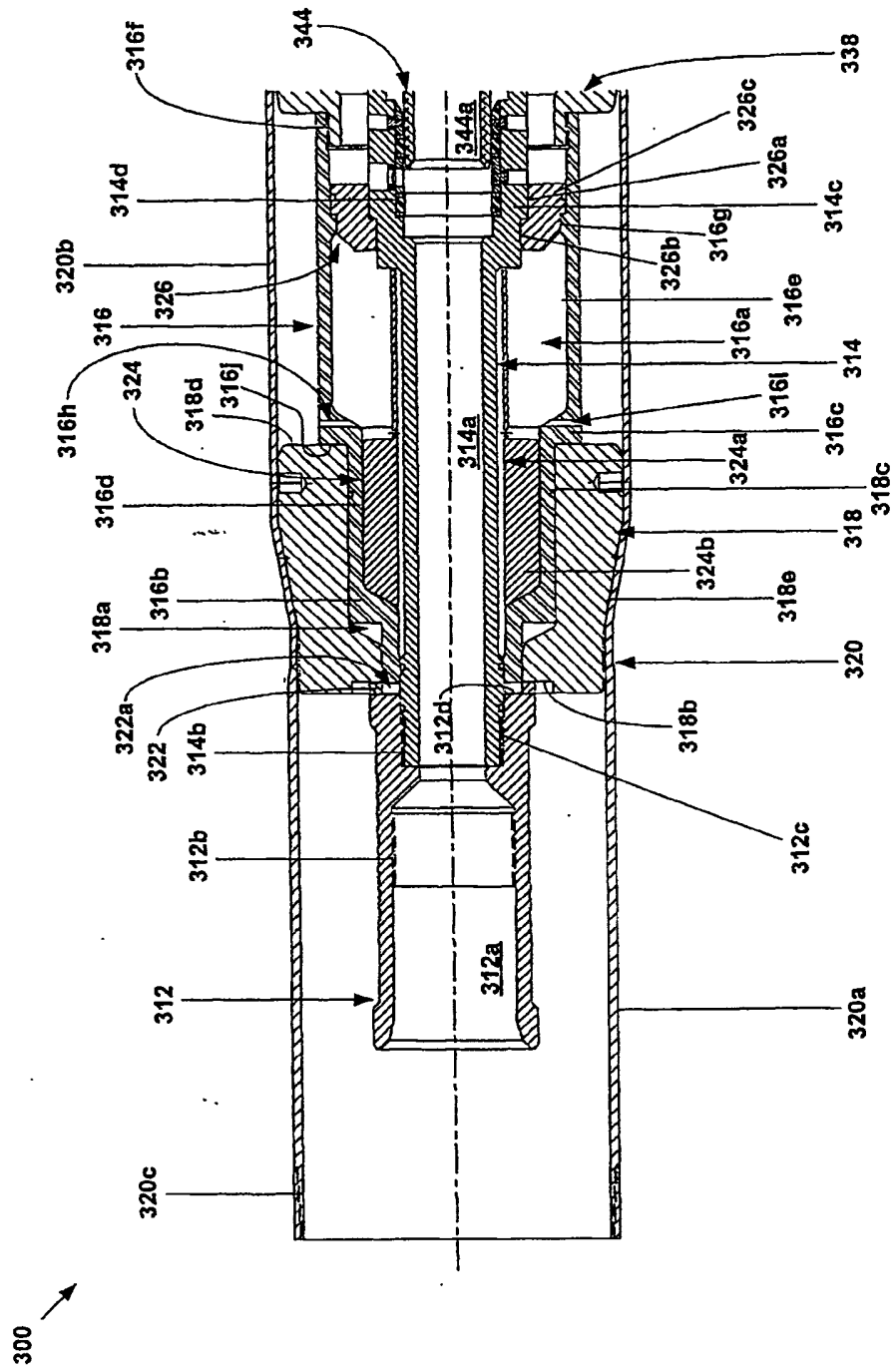
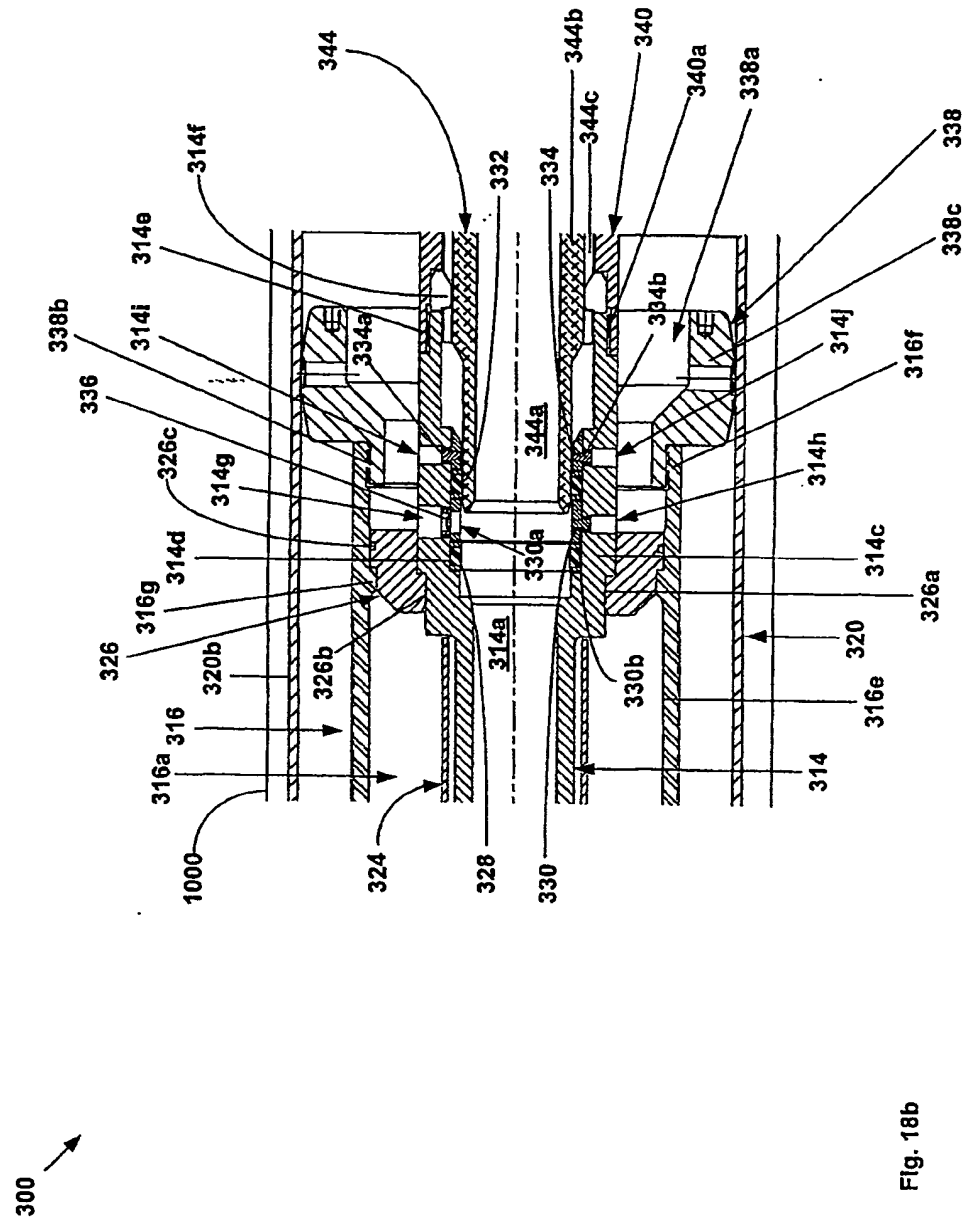


Fig. 18a



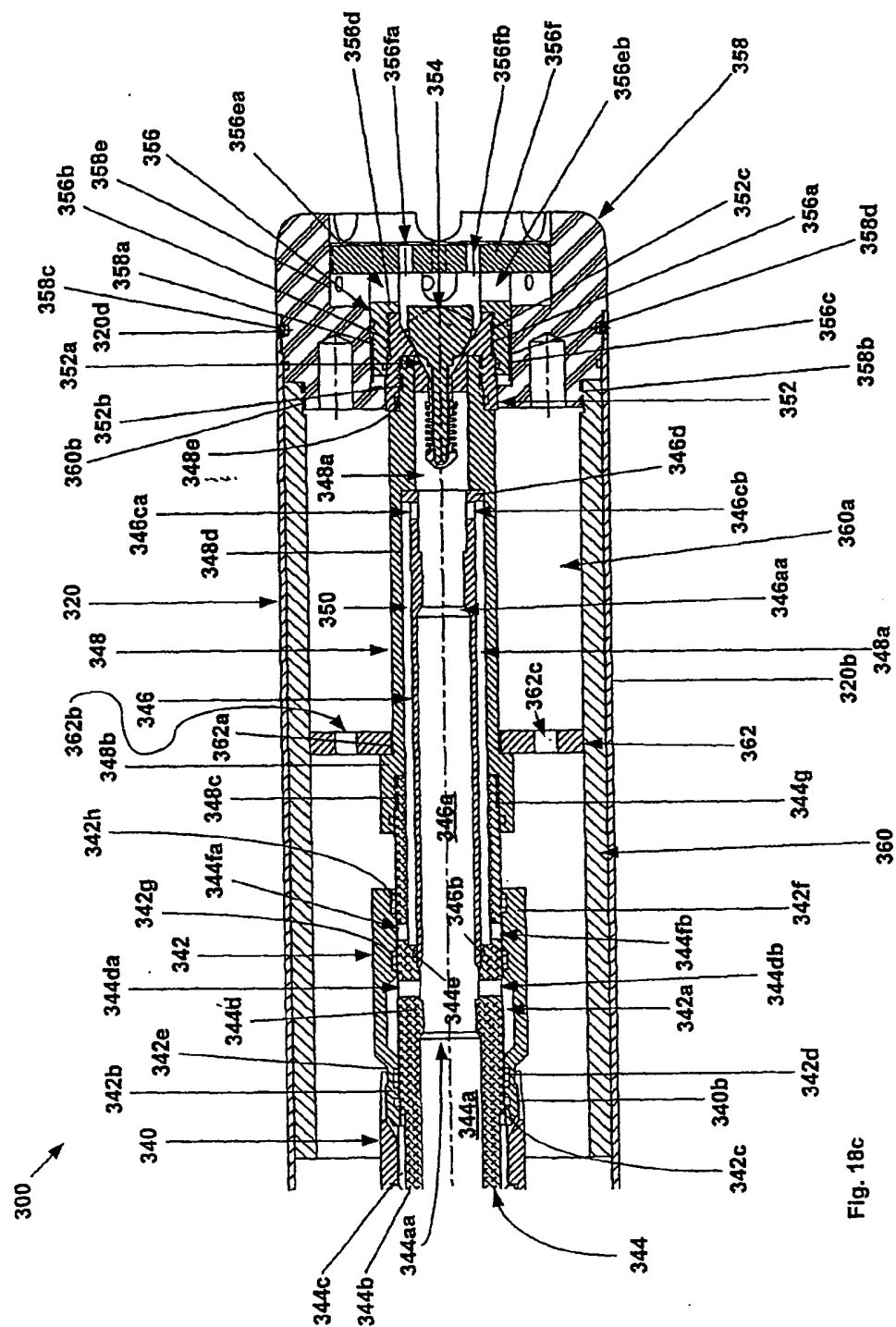


Fig. 18c

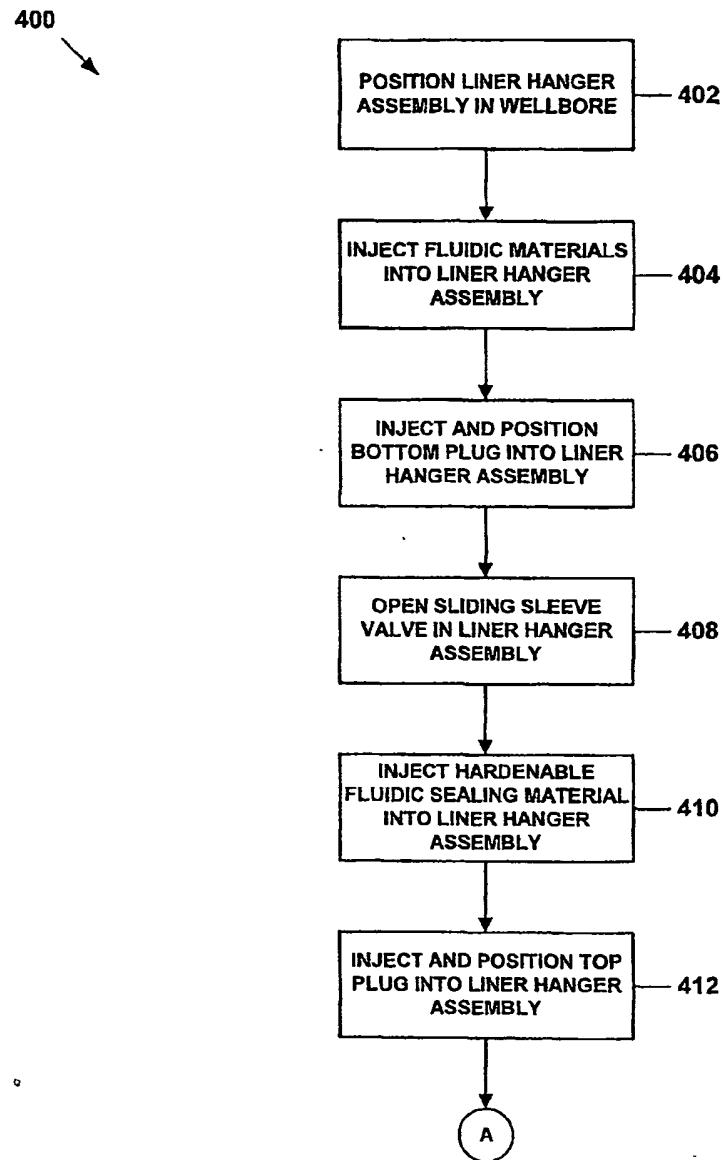


Fig. 19a

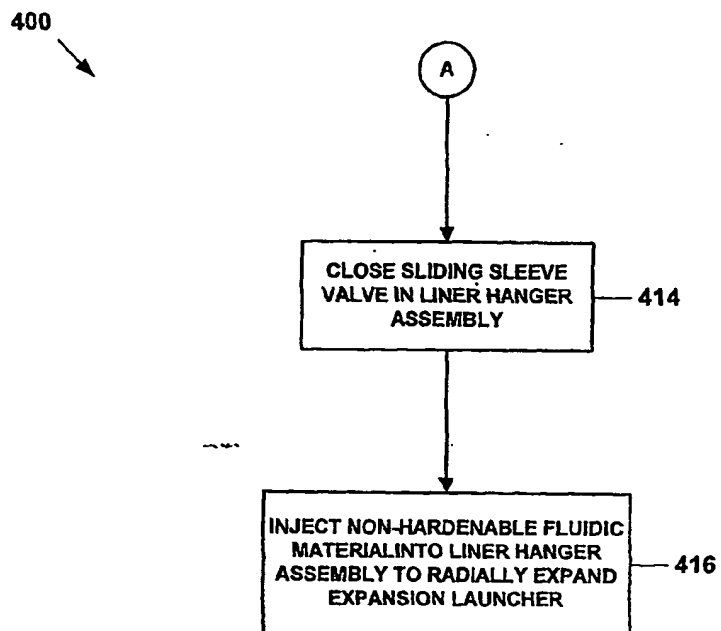


Fig. 19b

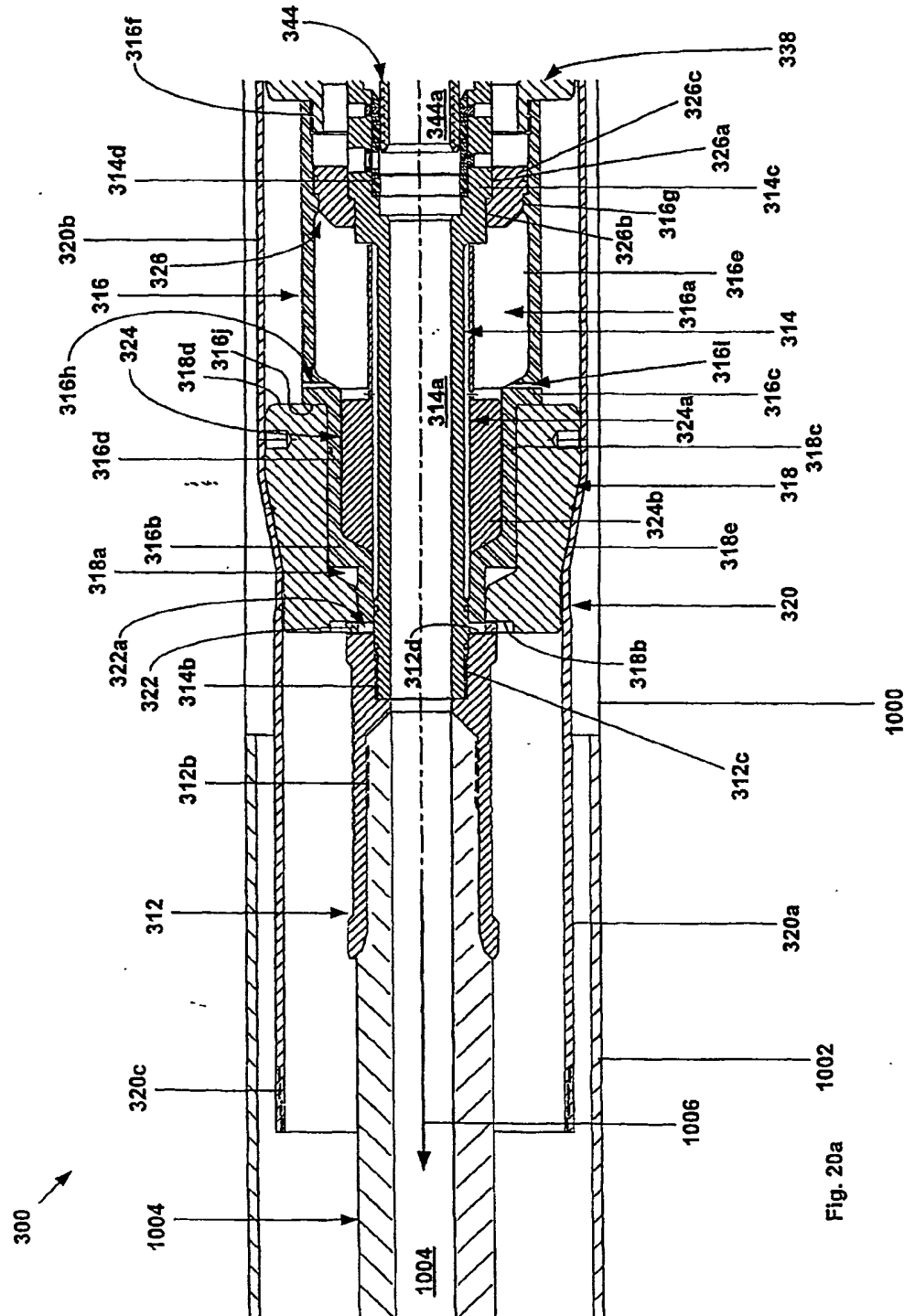


Fig. 20a

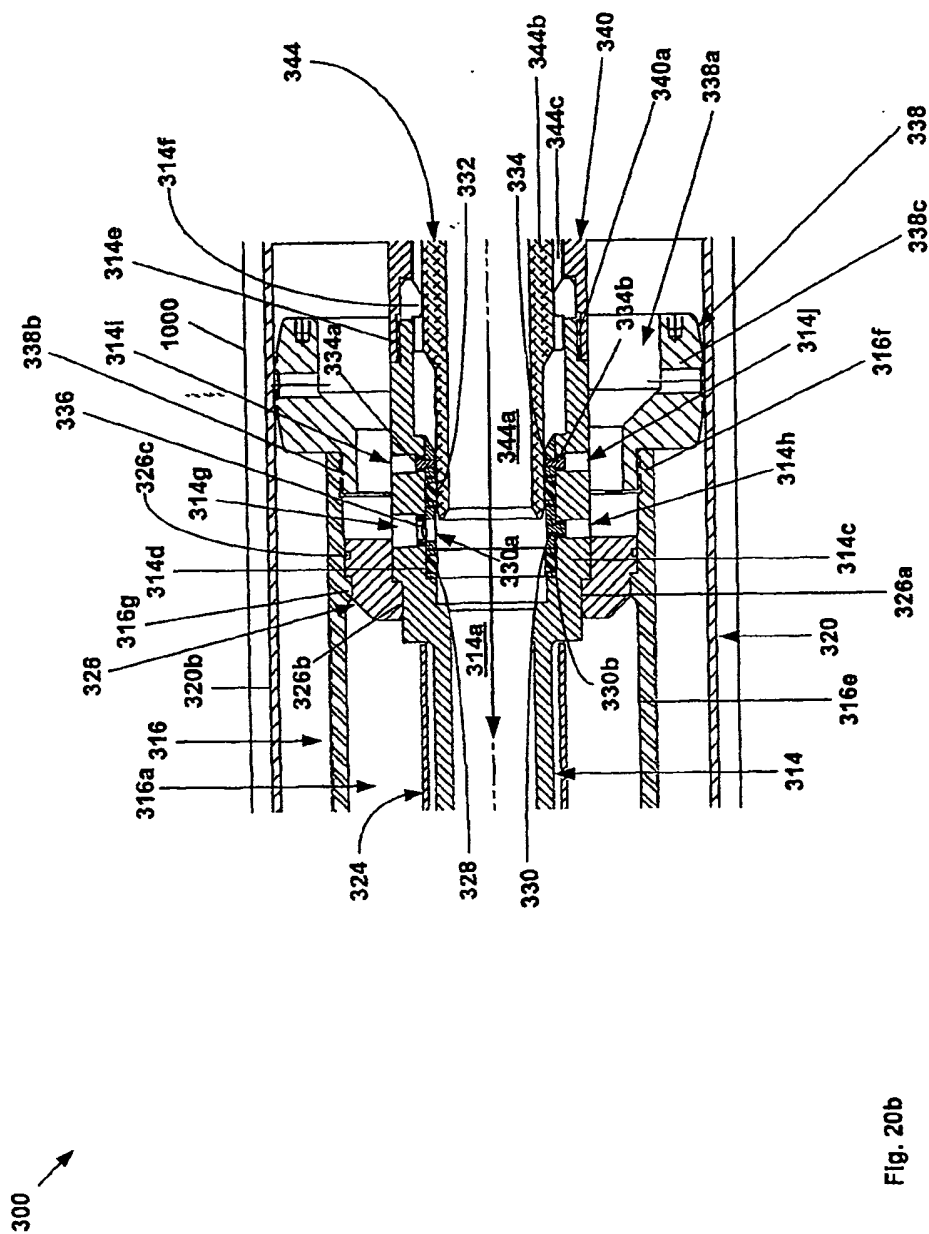


Fig. 20b

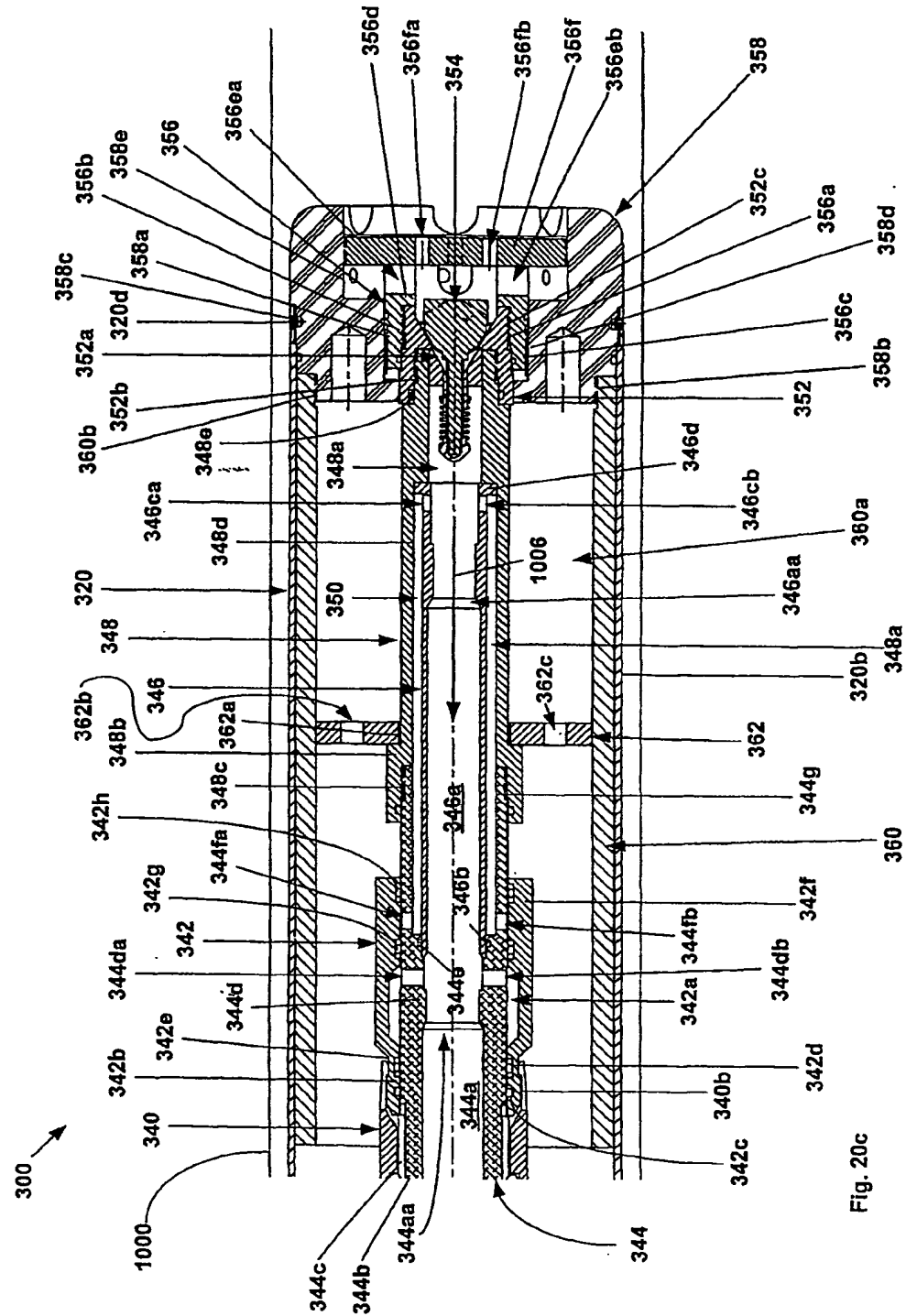


Fig. 20c

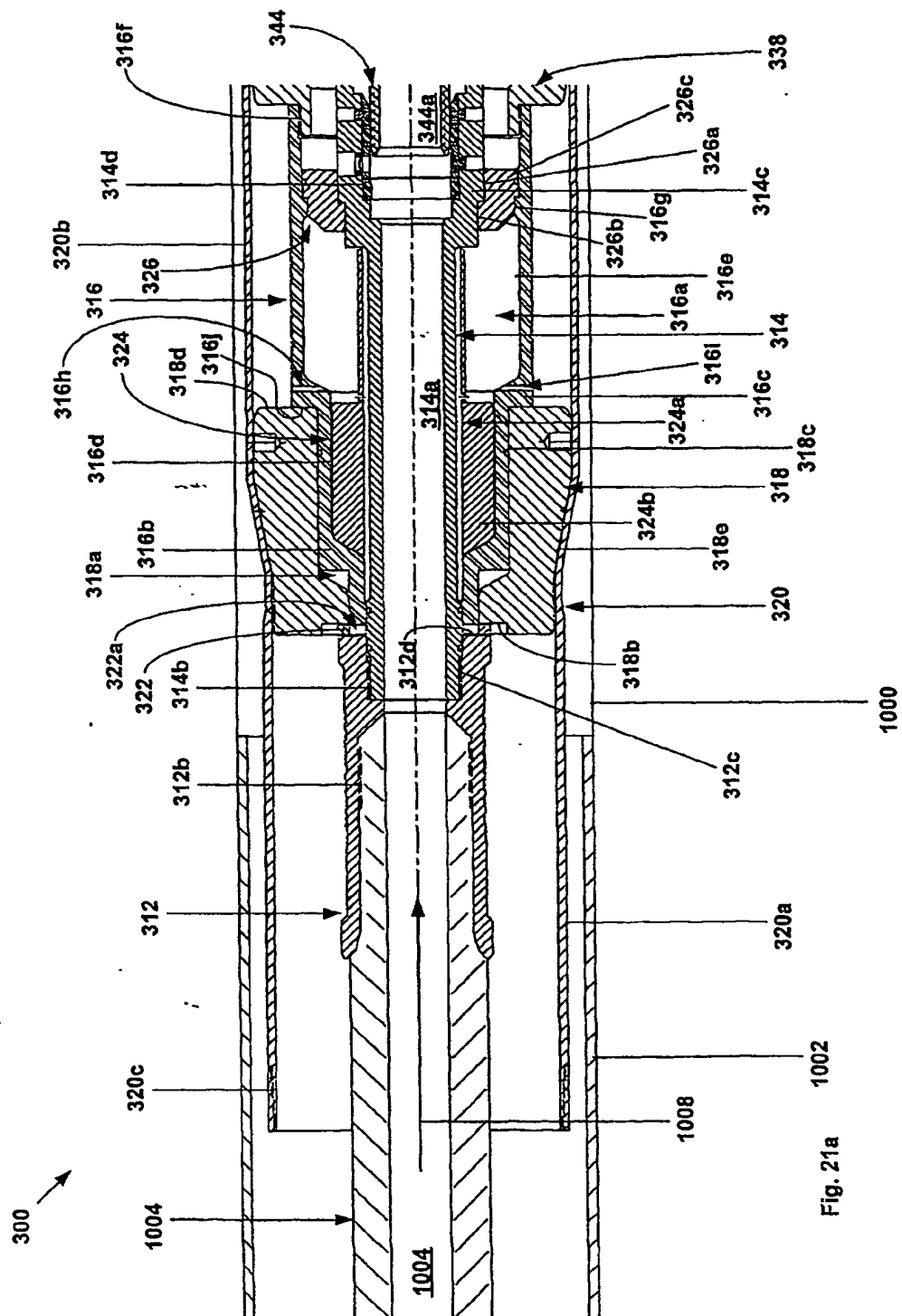


Fig. 21a

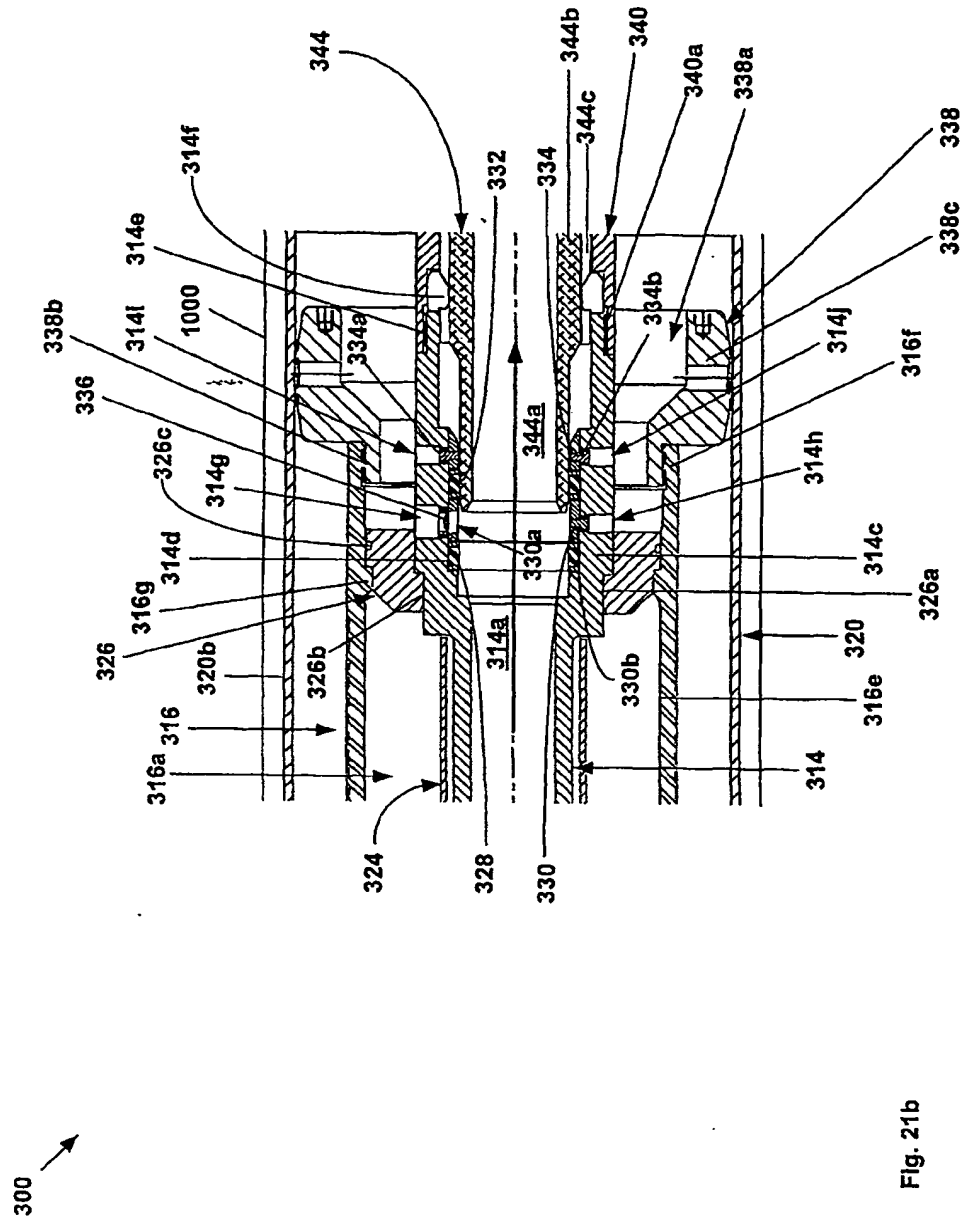


Fig. 21b

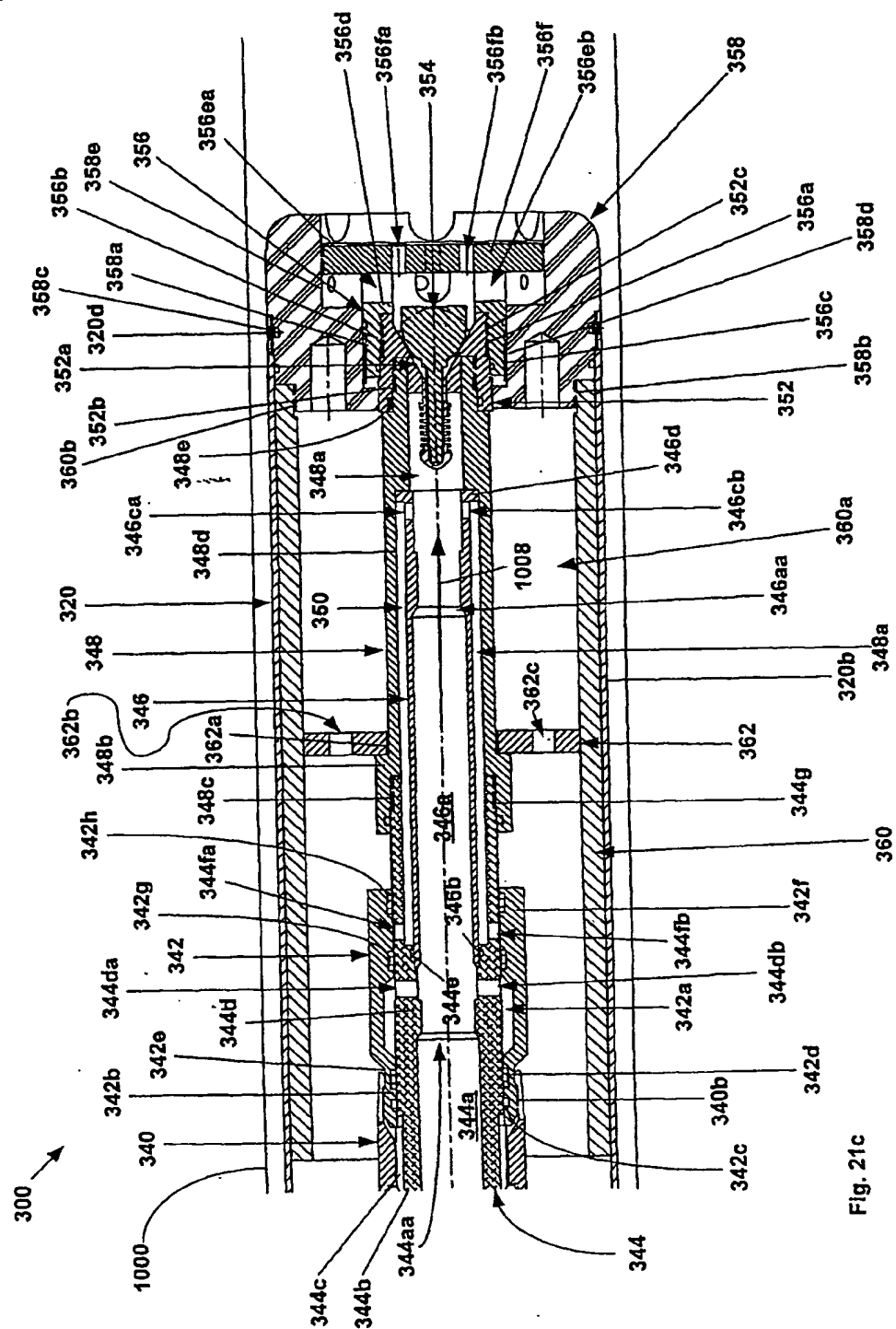


Fig. 21c

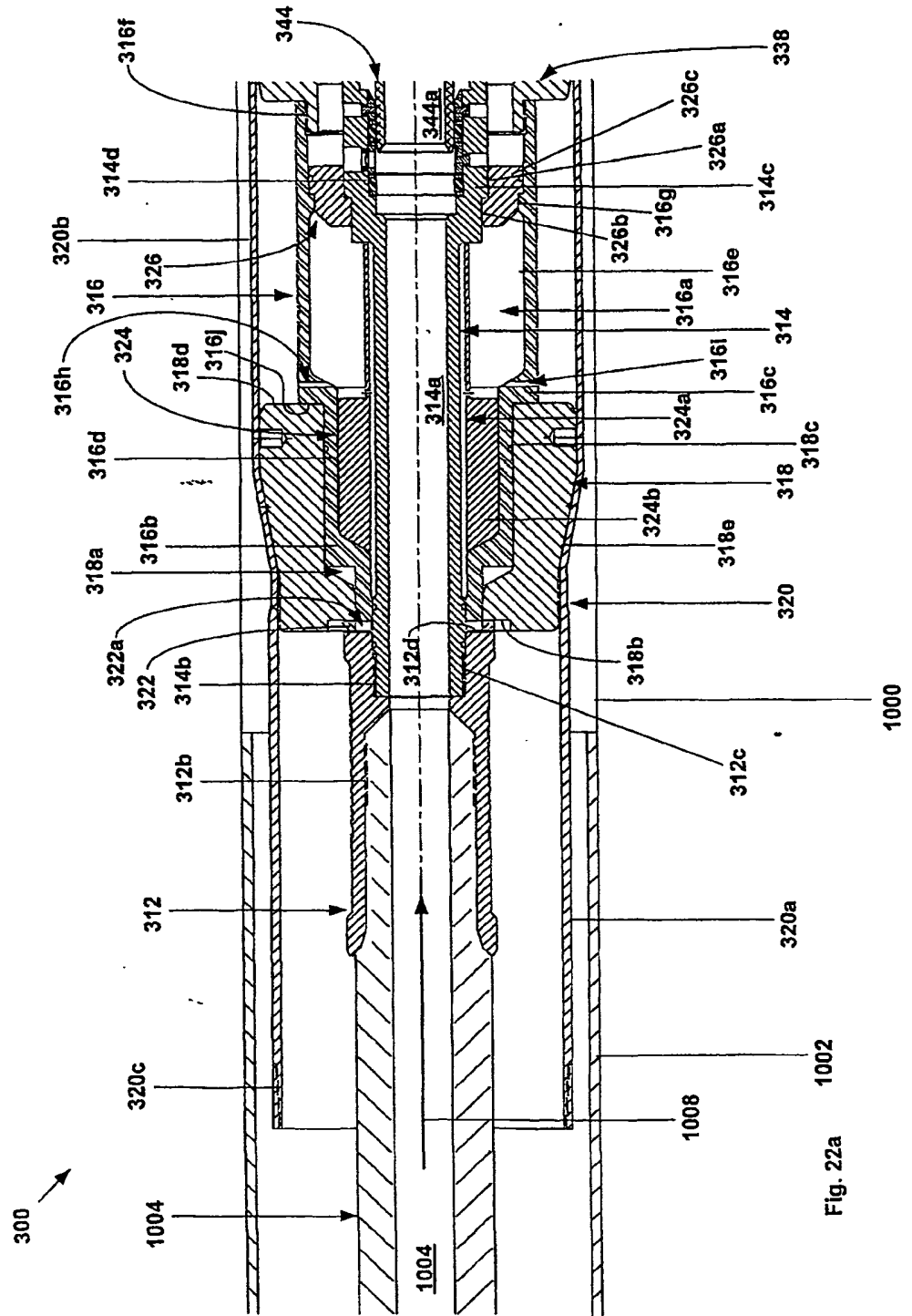


Fig. 22a

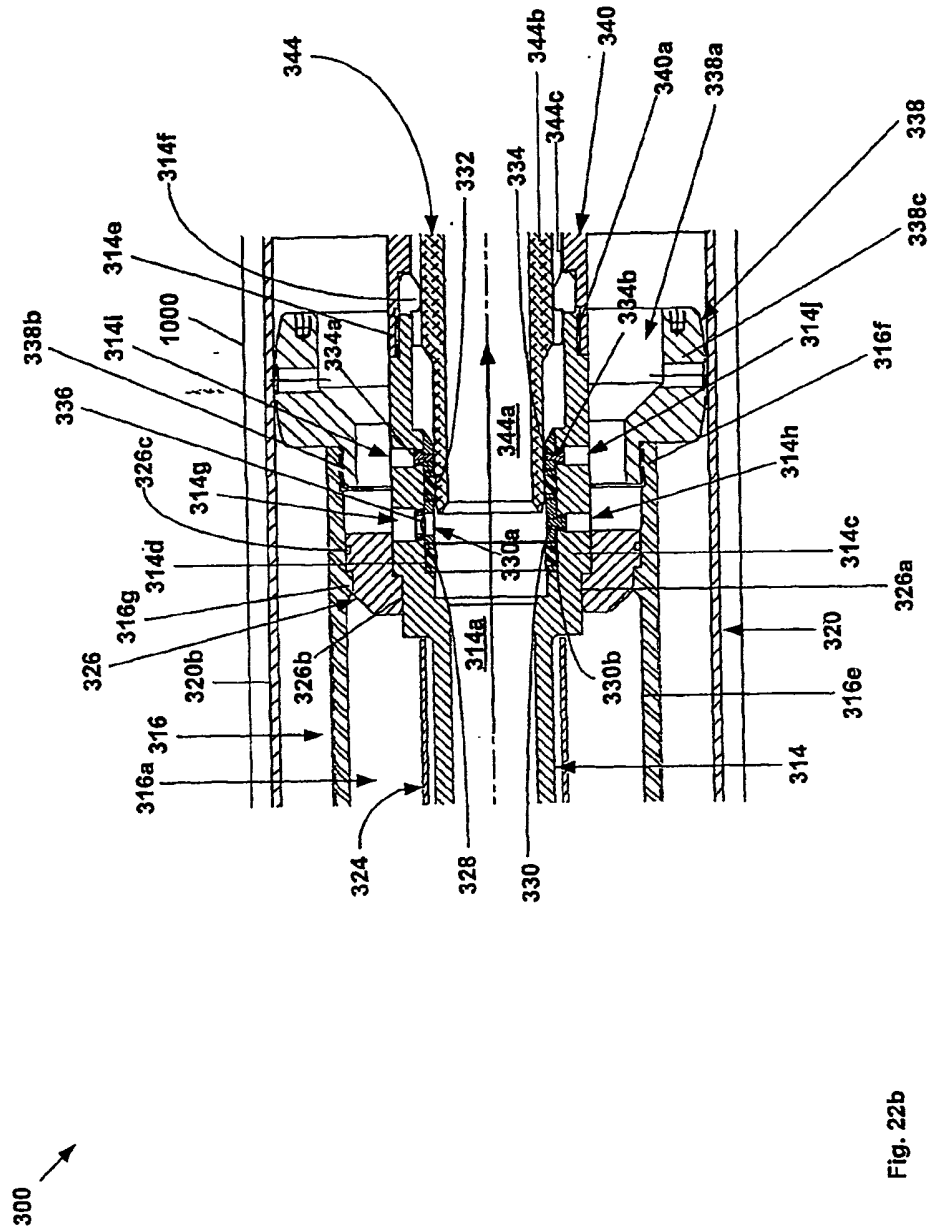


Fig. 22b

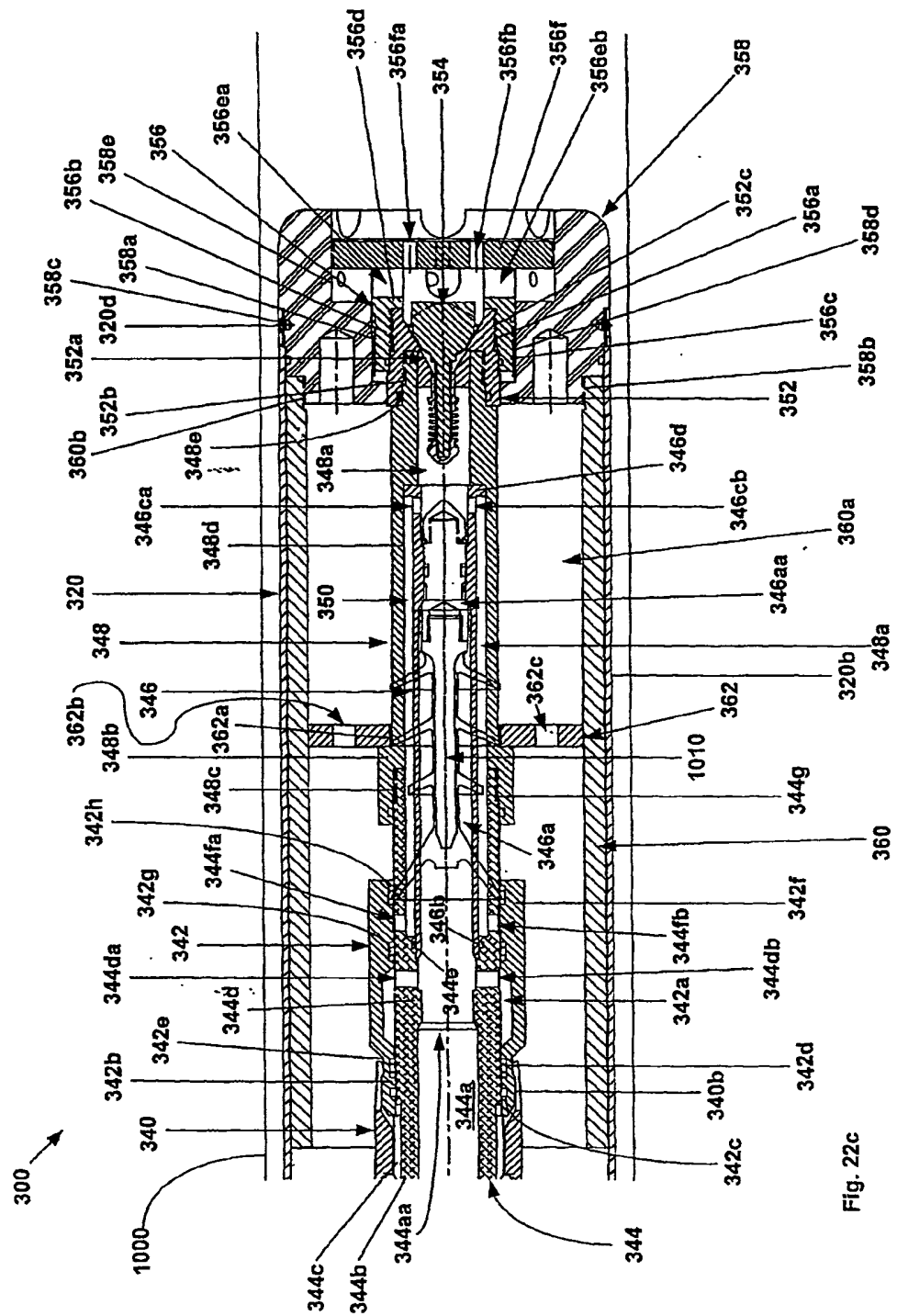


Fig. 22c

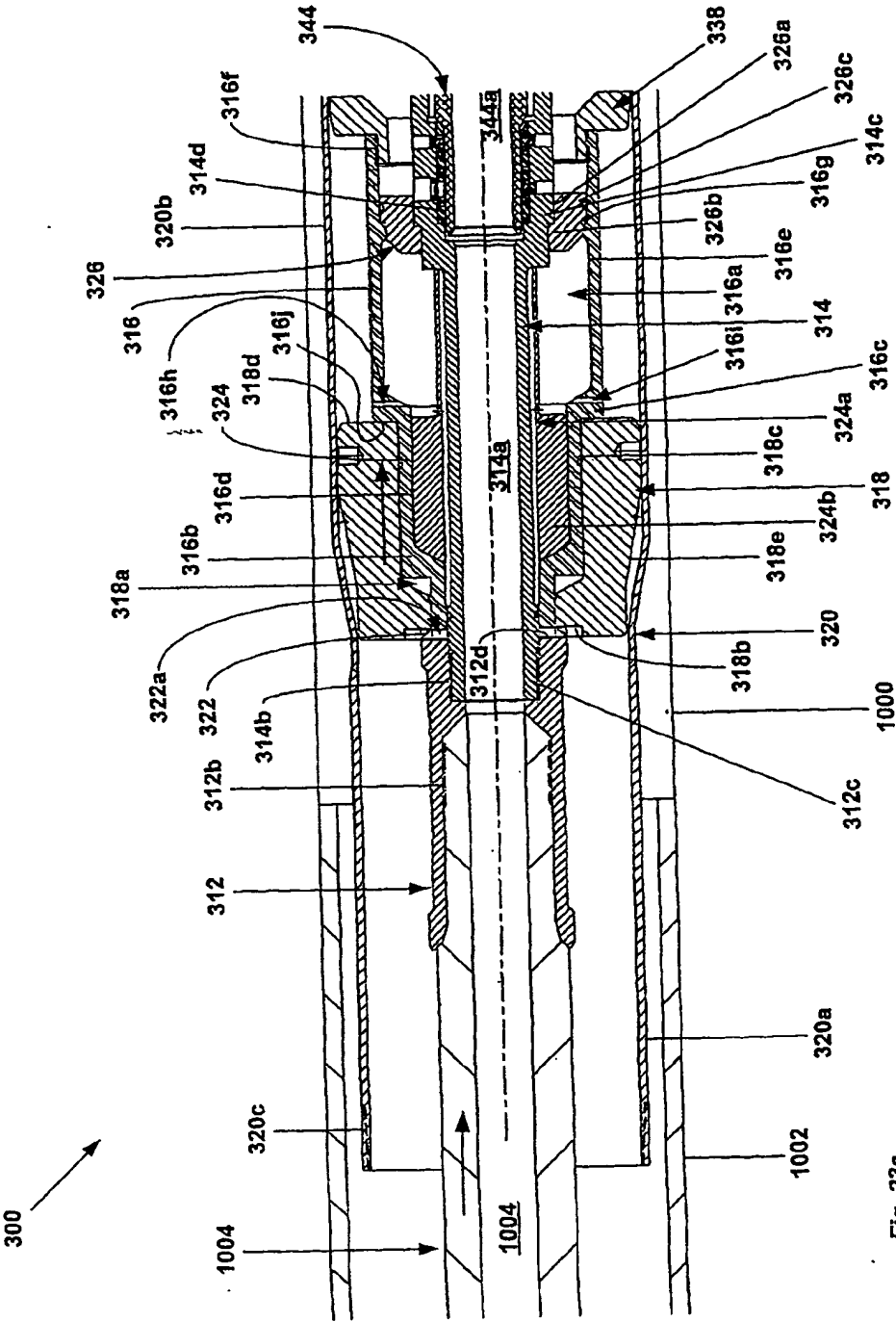


Fig. 23a

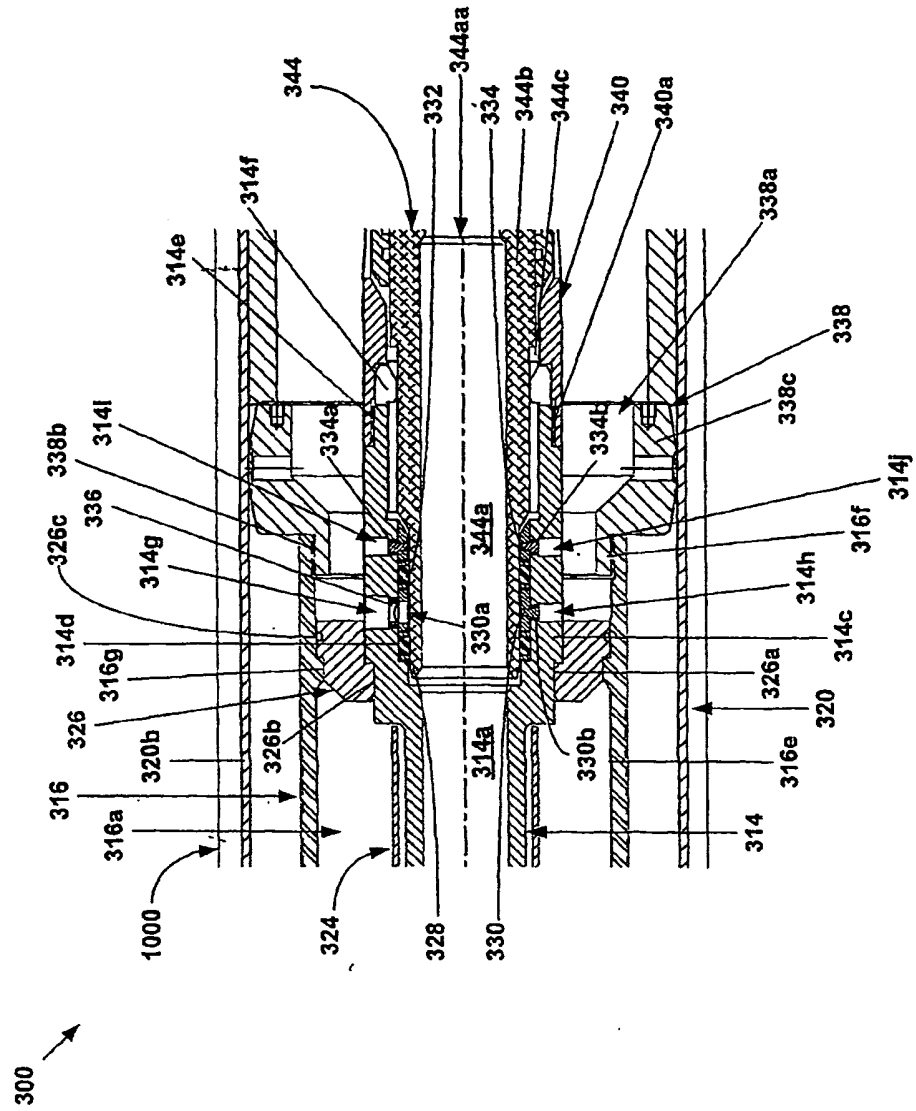


Fig. 23b

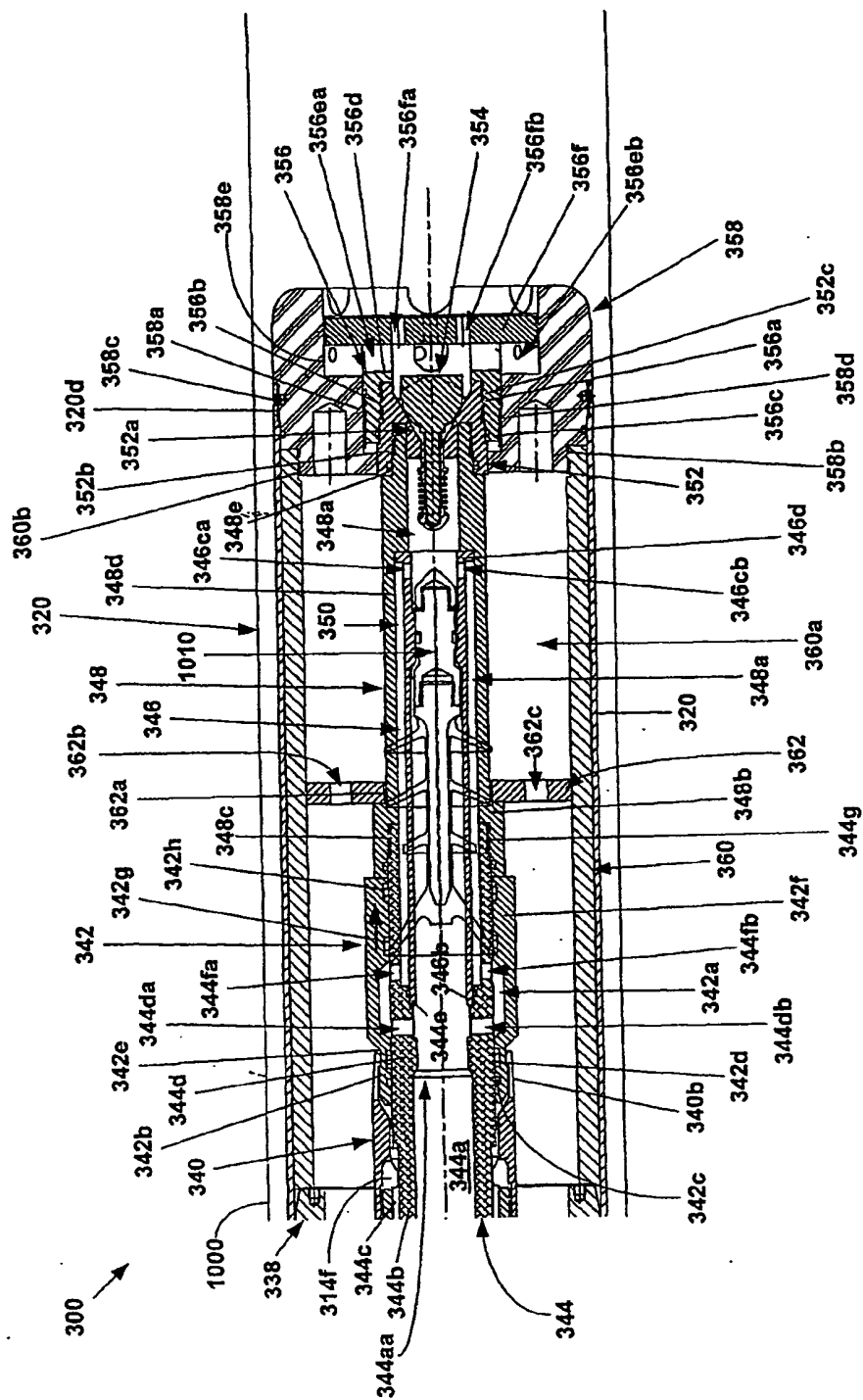
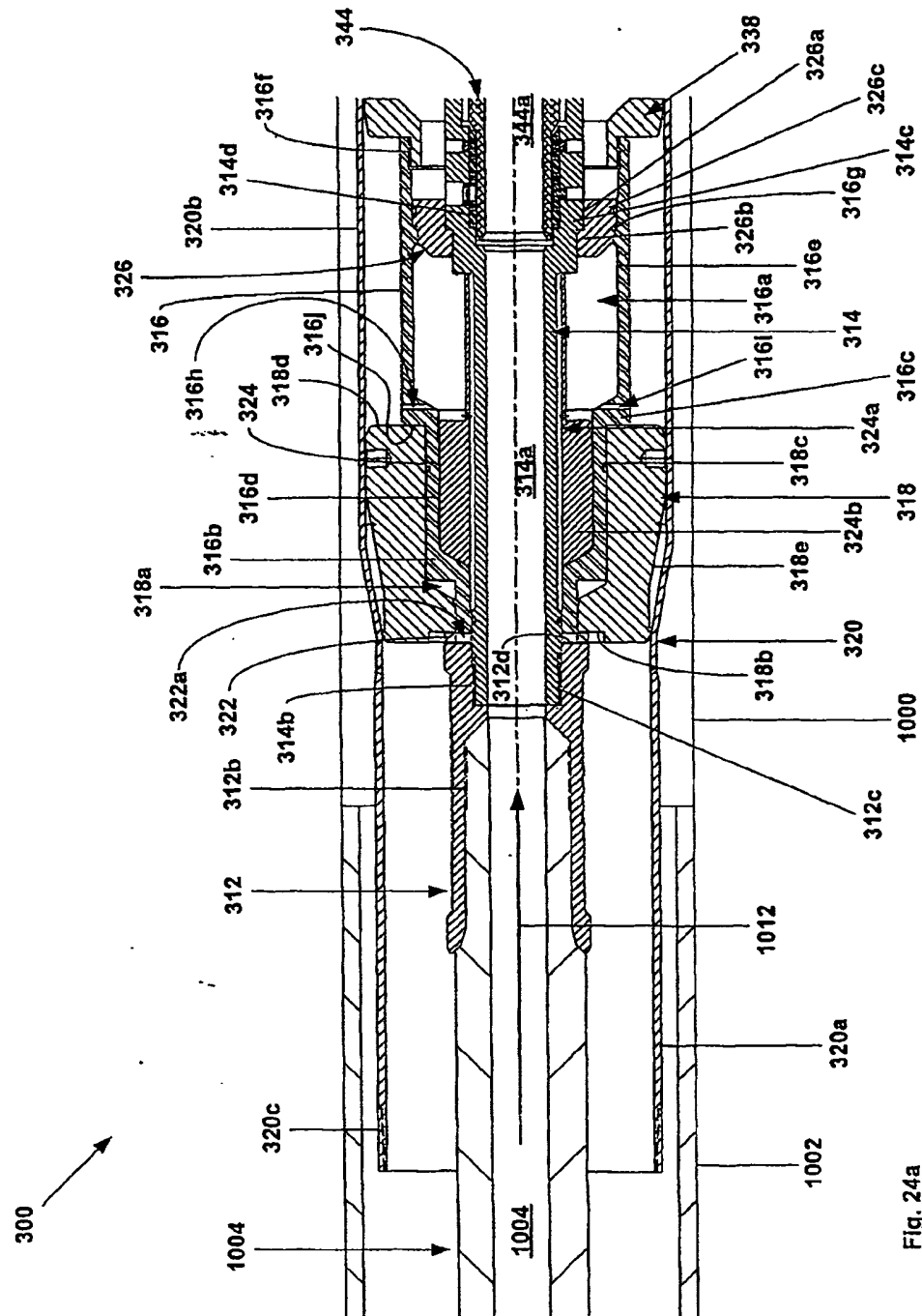


Fig. 23c



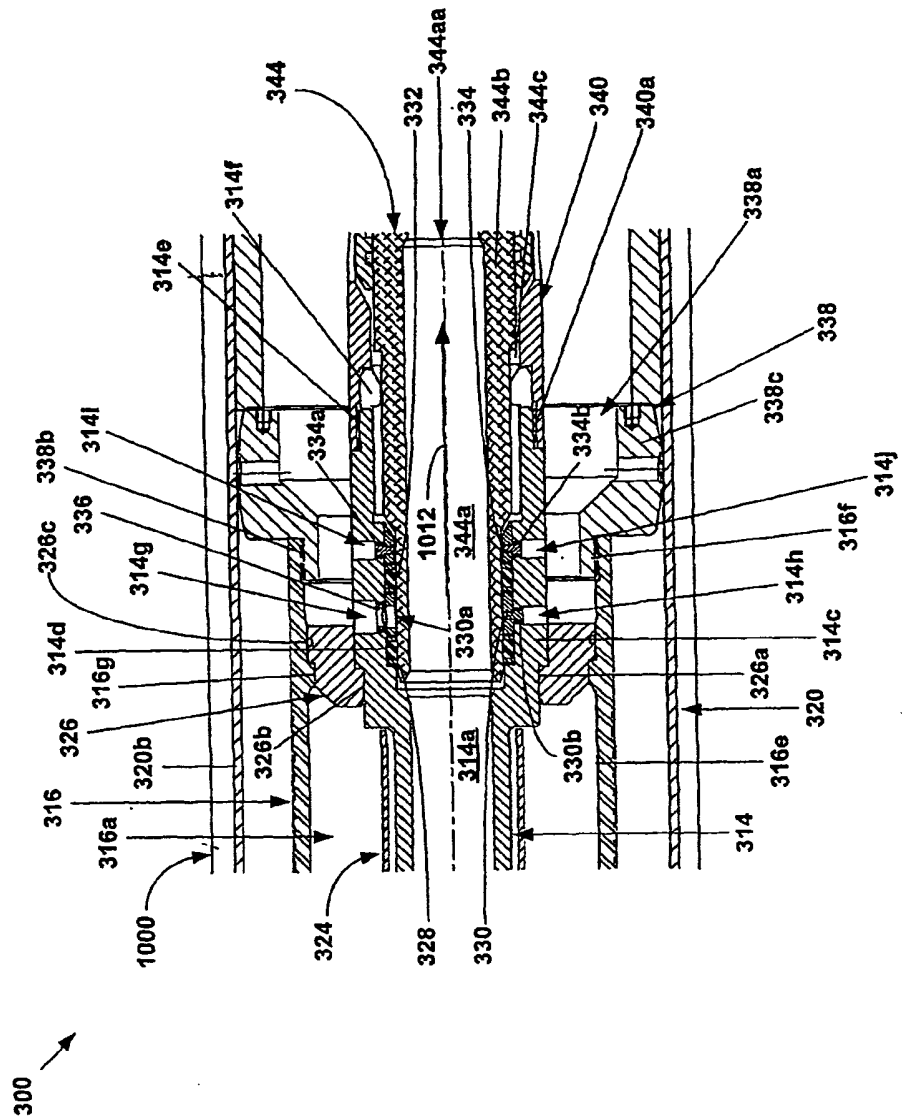


Fig. 24b

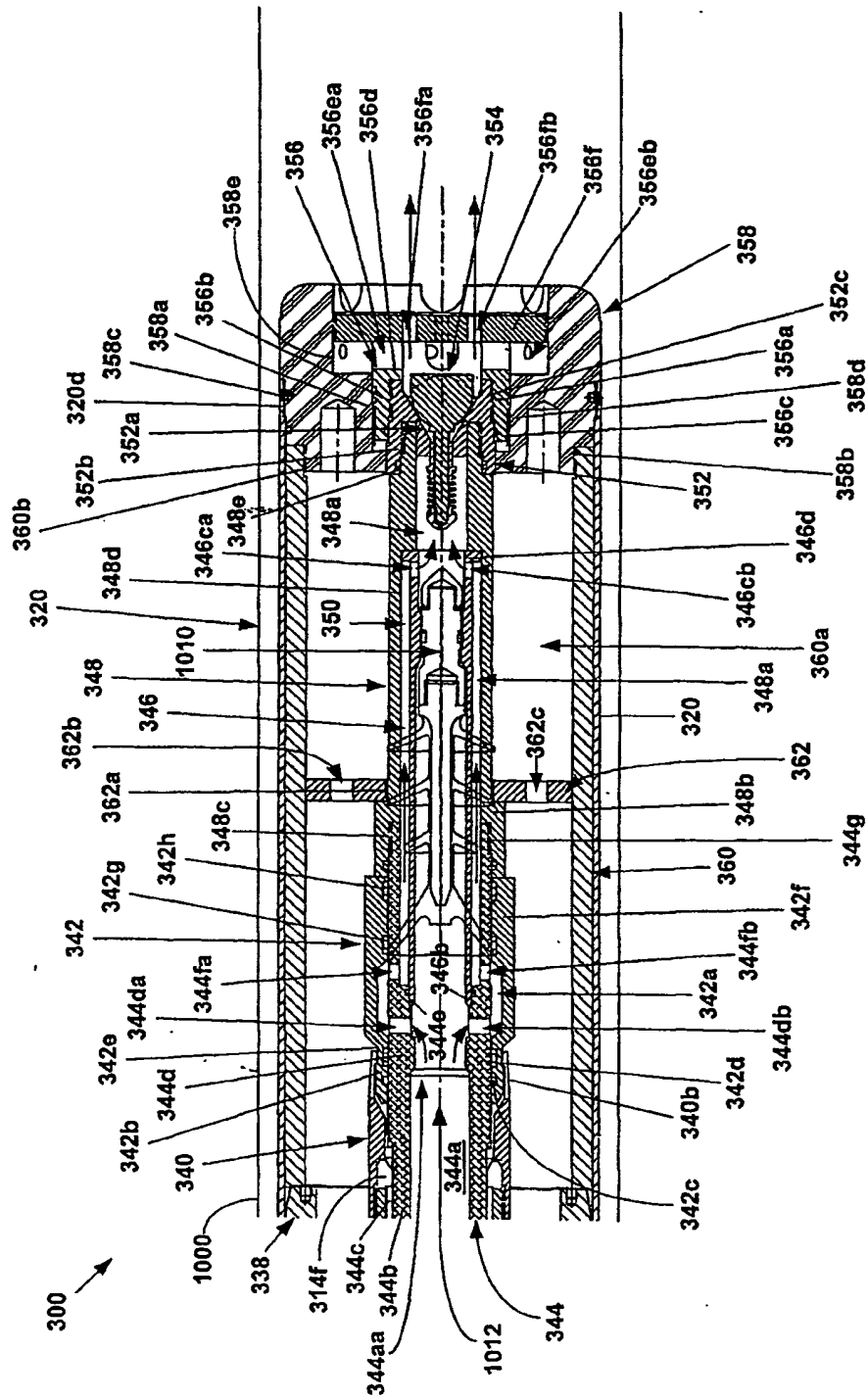
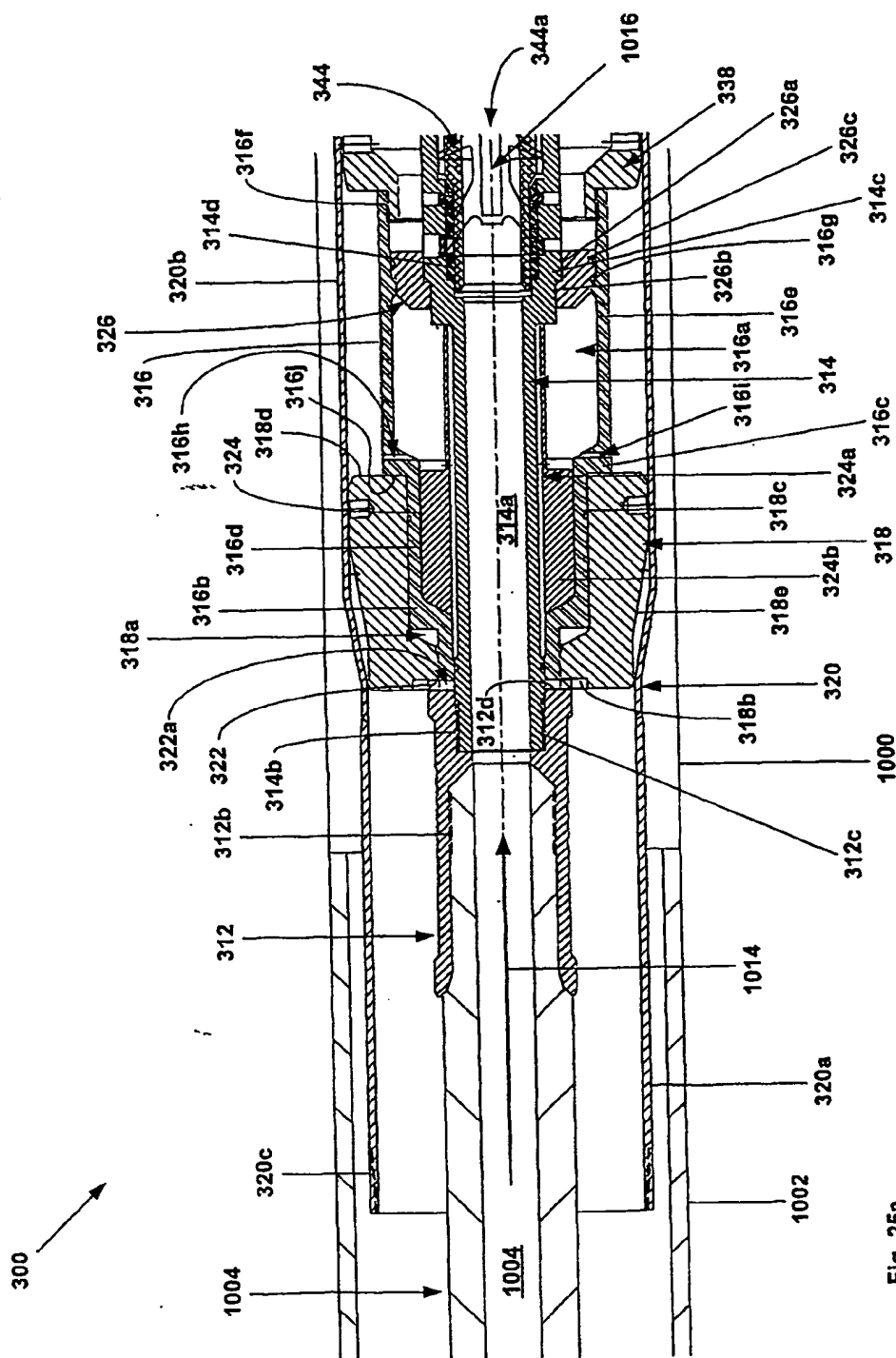


Fig. 24c



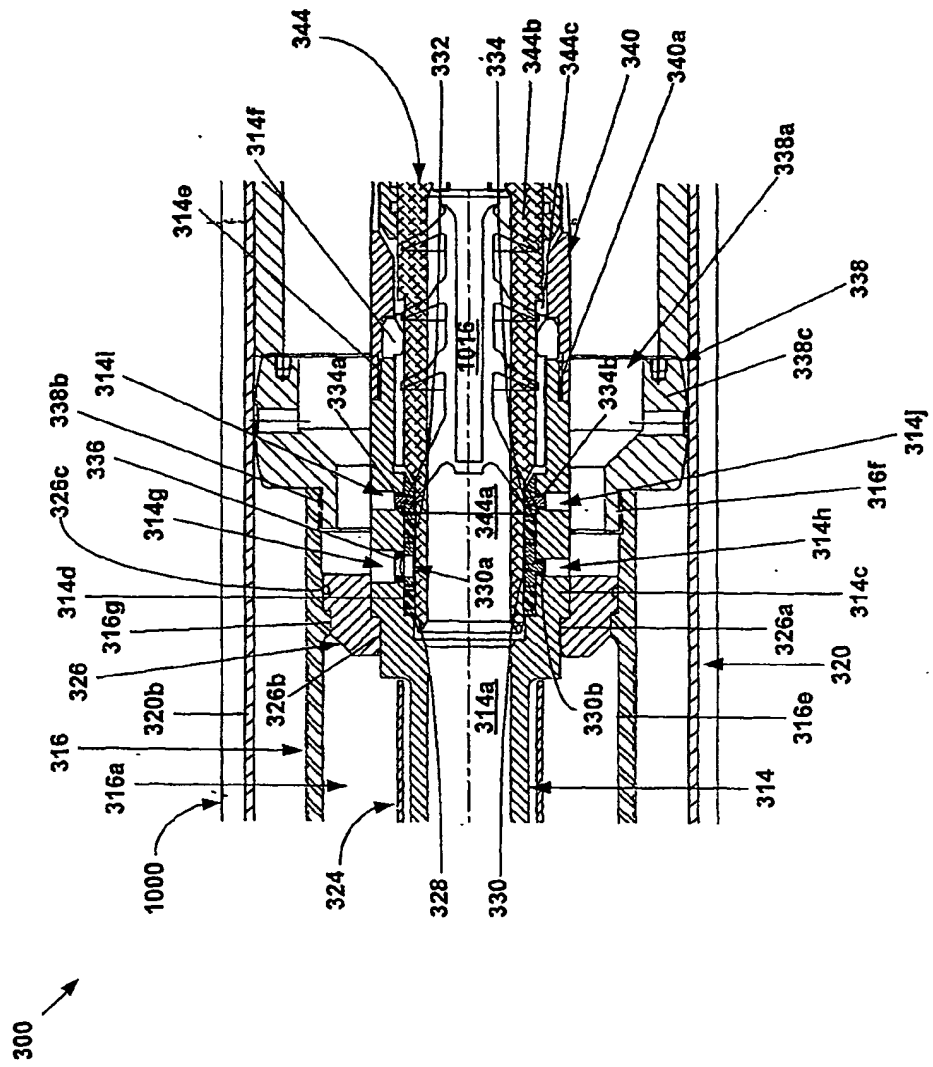


Fig. 25b

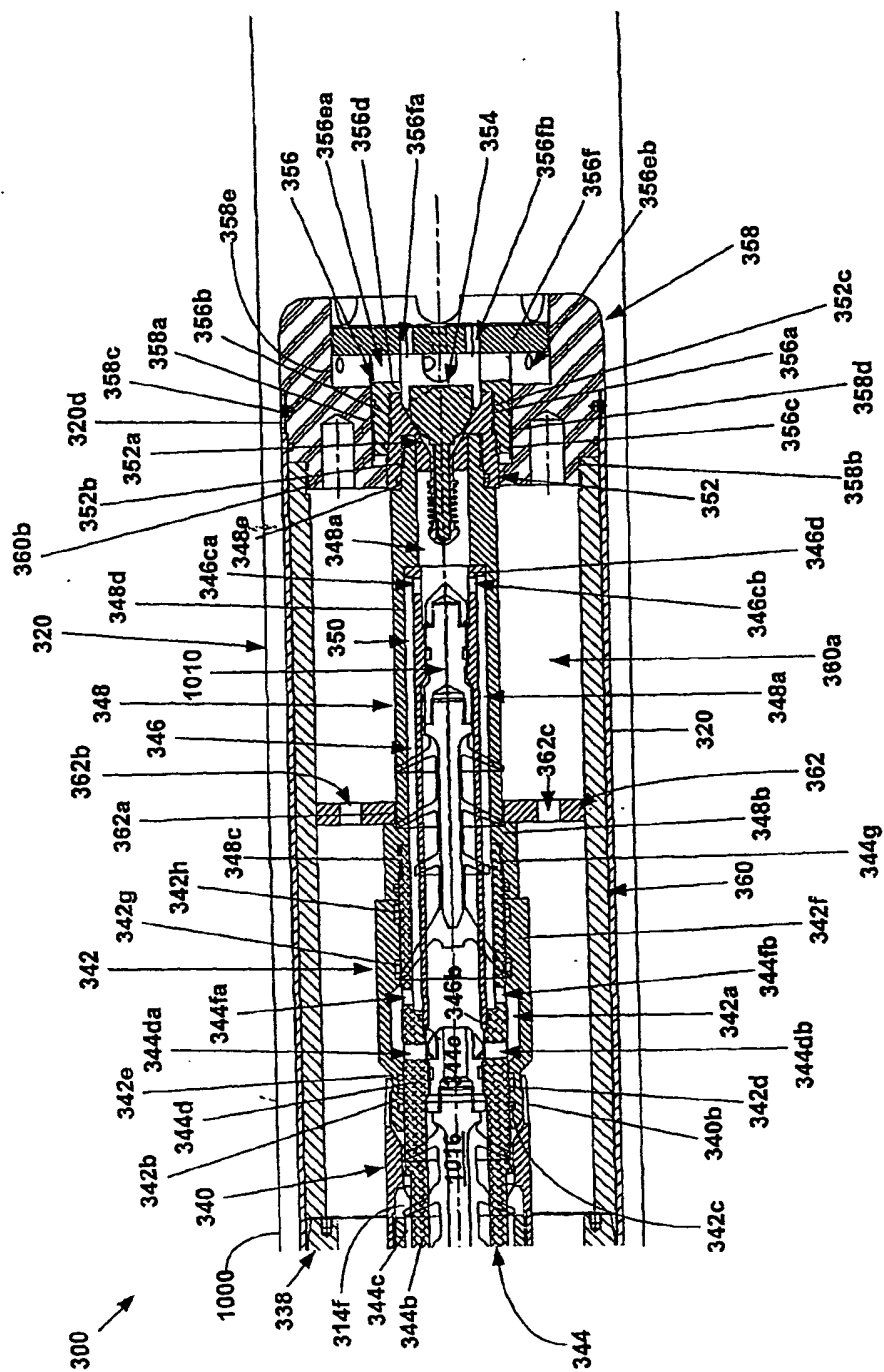


Fig. 25c

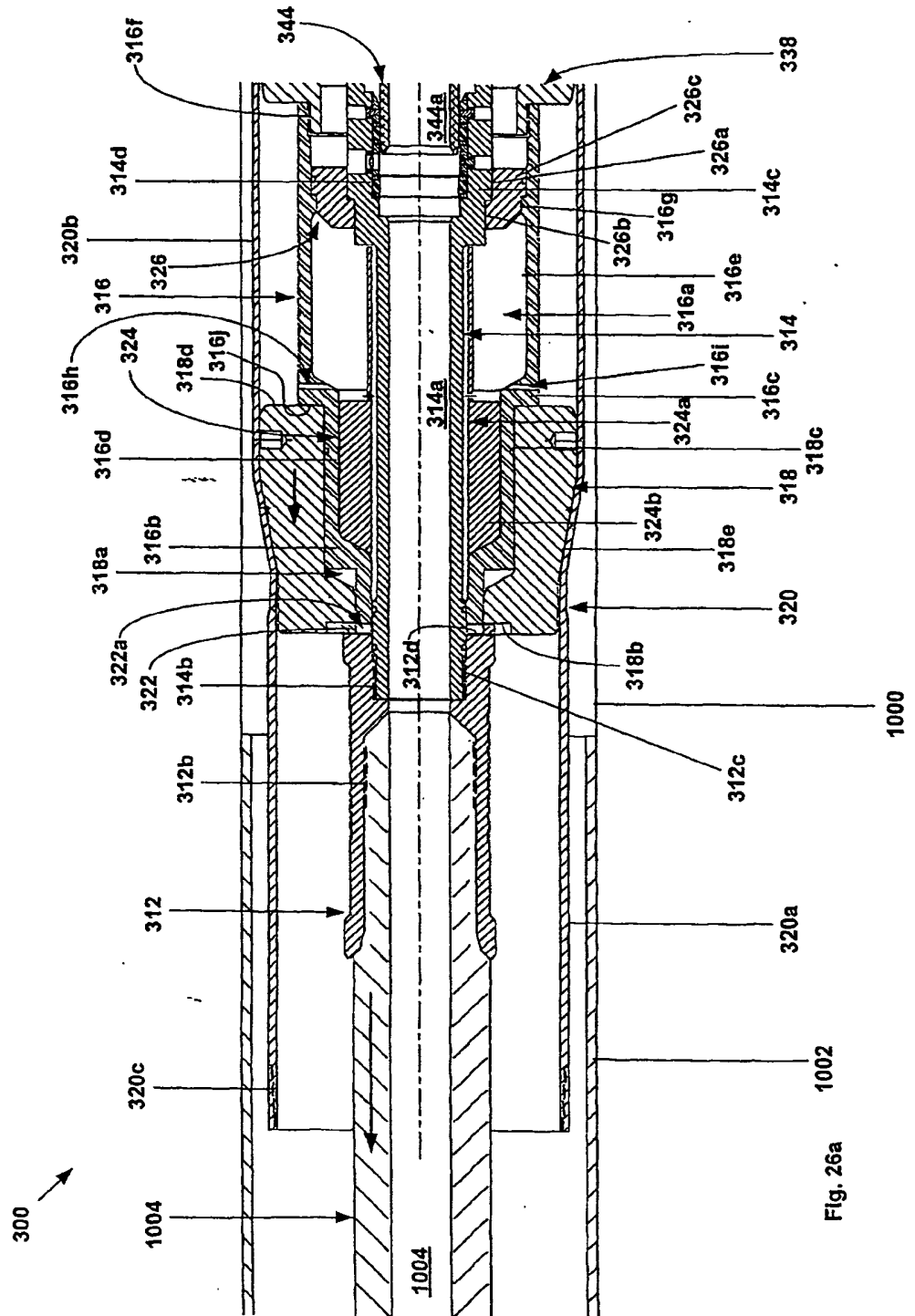
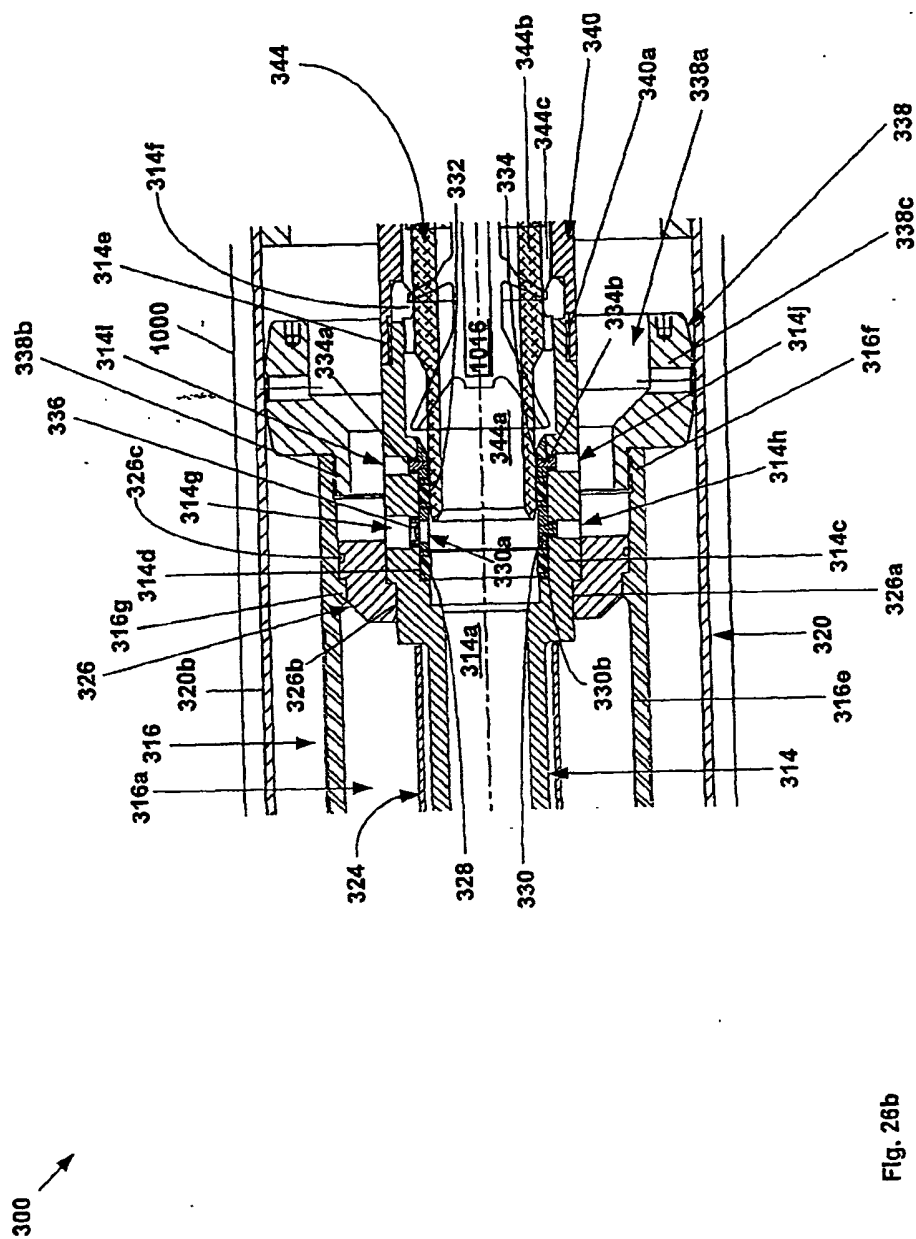


Fig. 26a



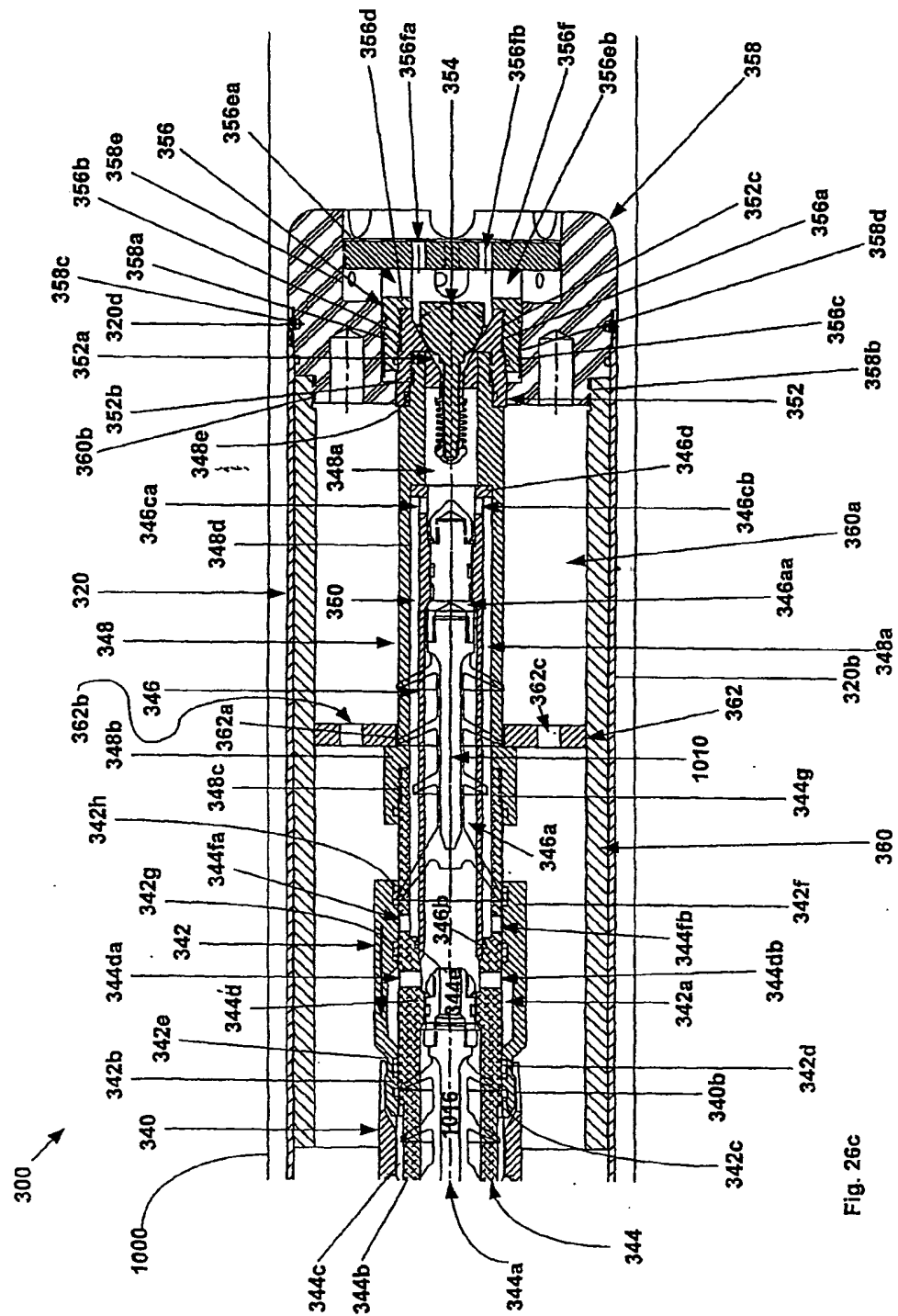


Fig. 26c

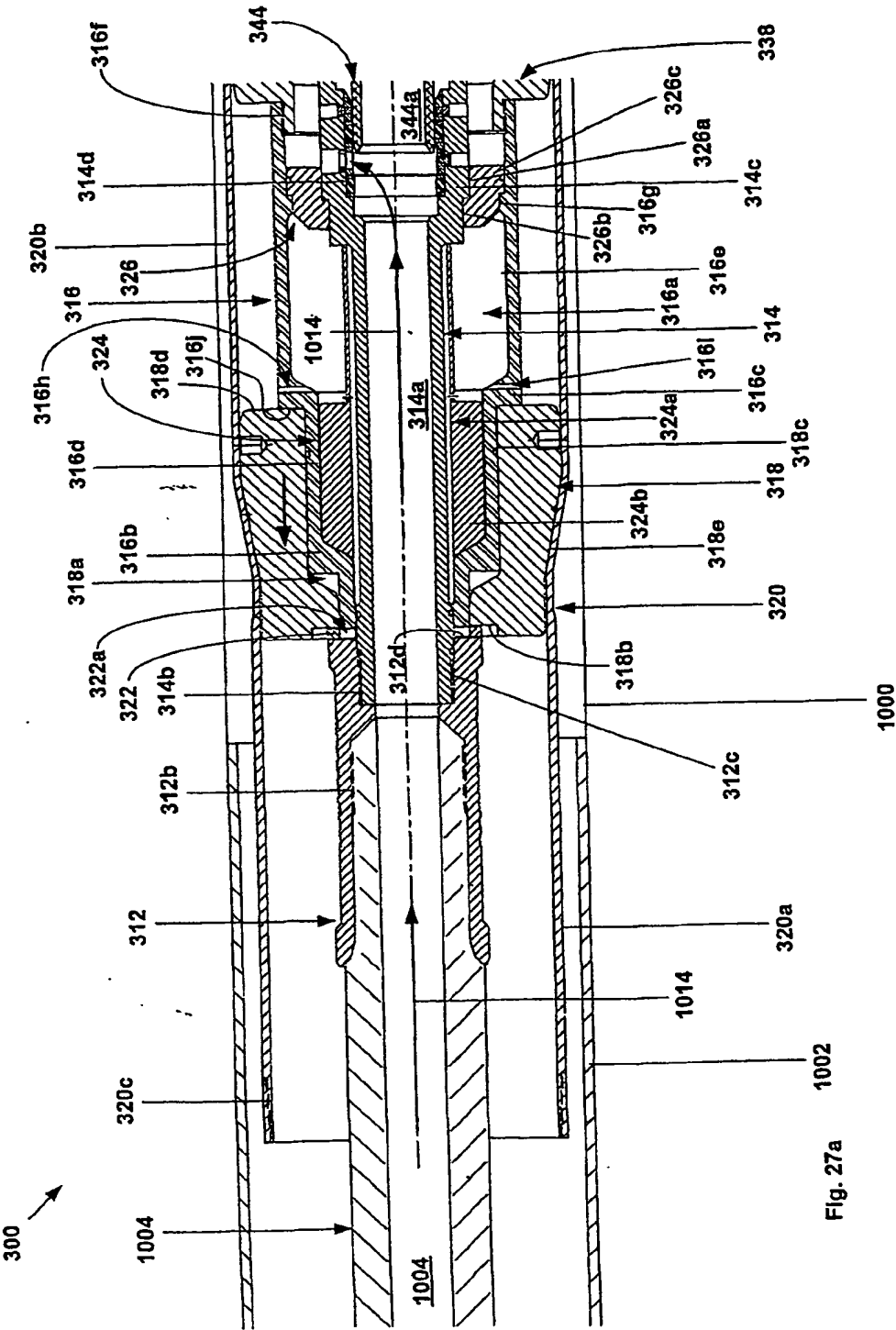
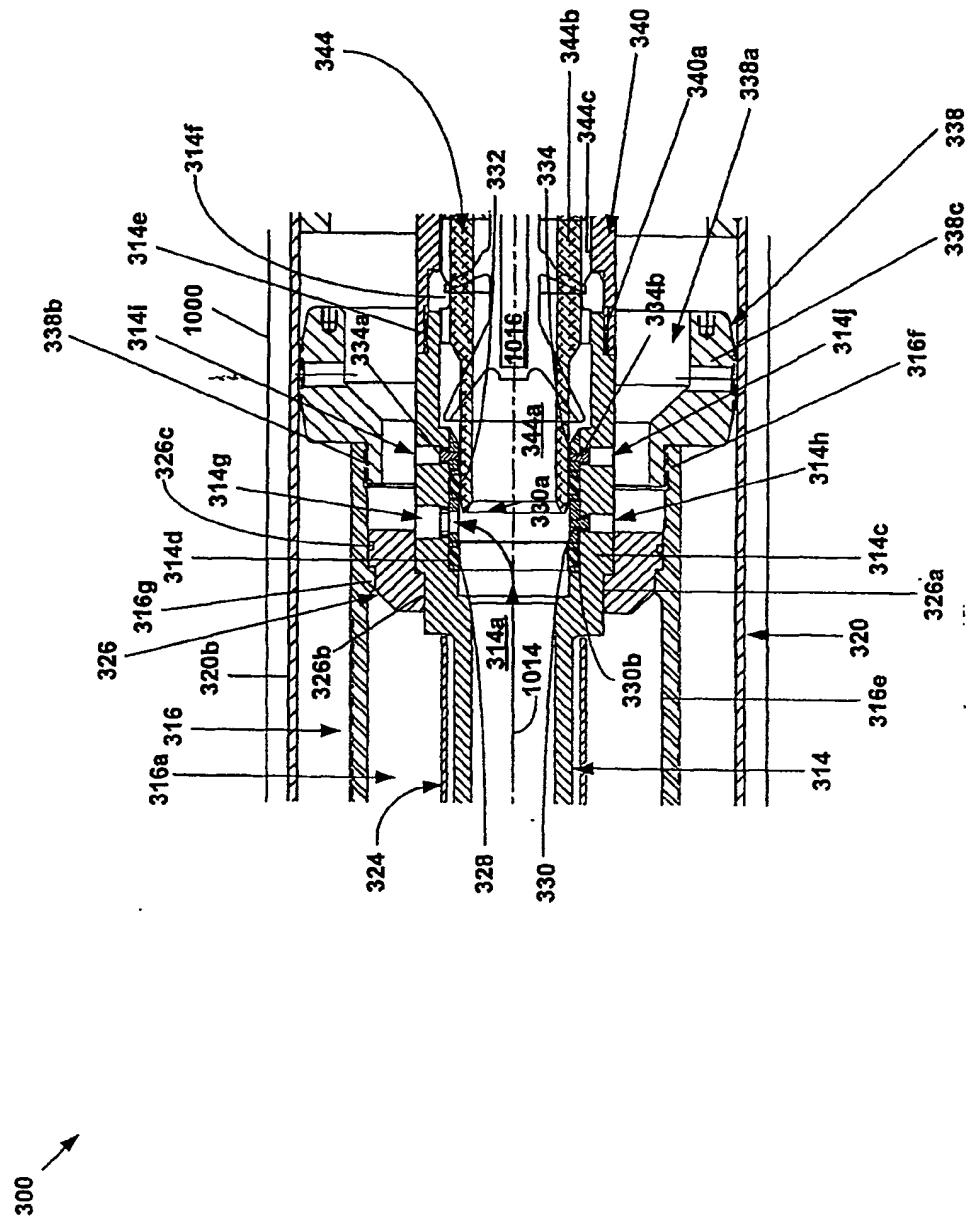


Fig. 27a



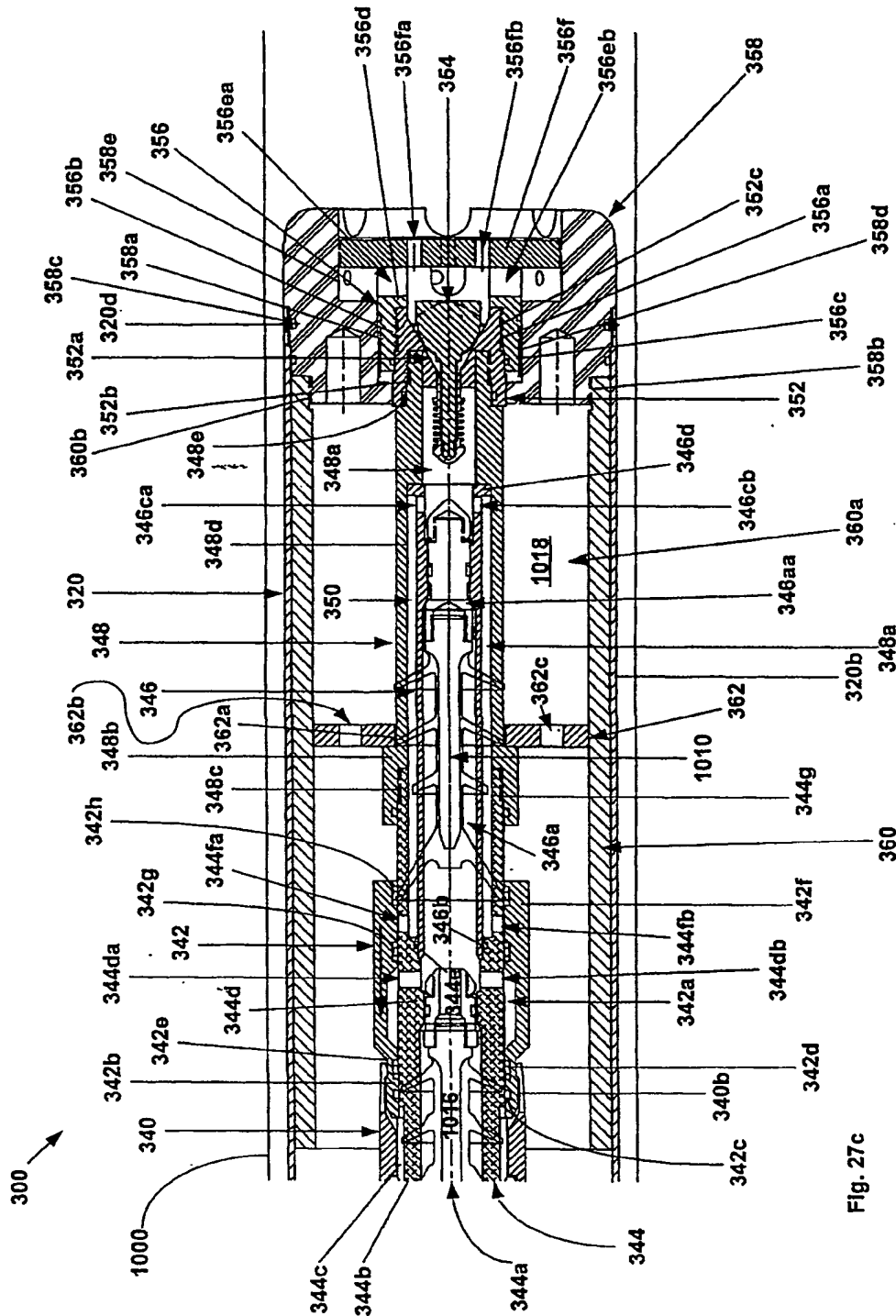


Fig. 27c

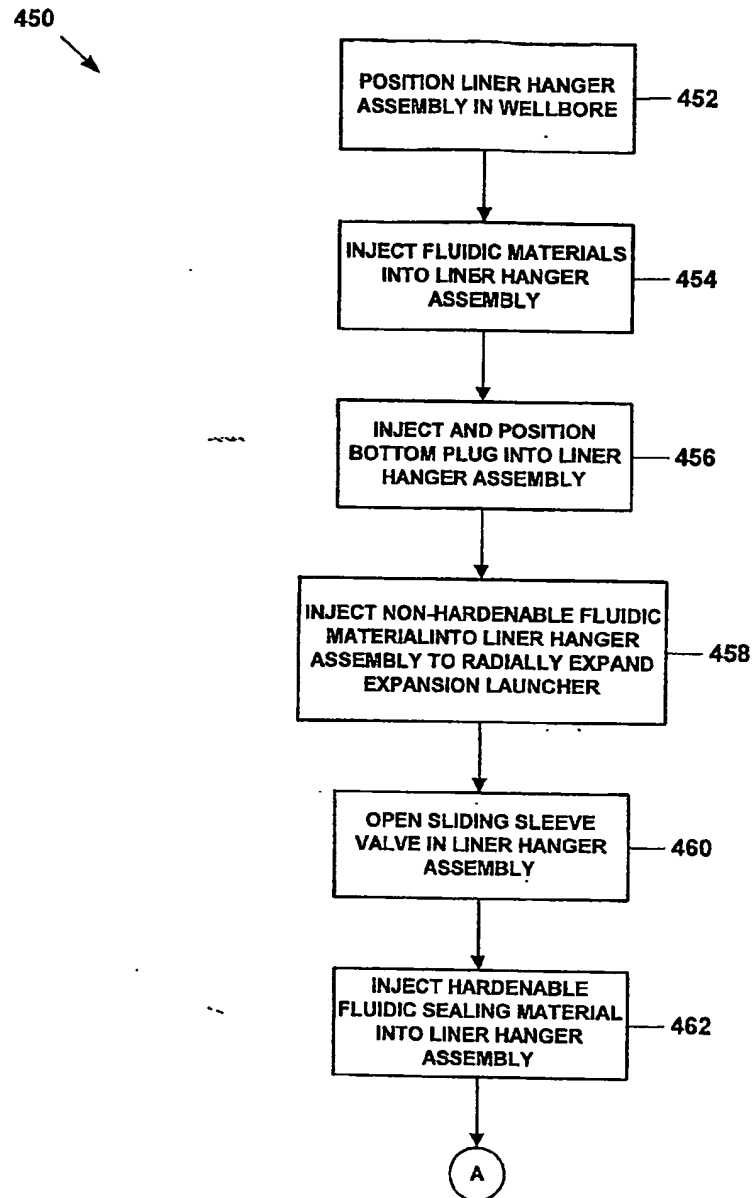


Fig. 28a

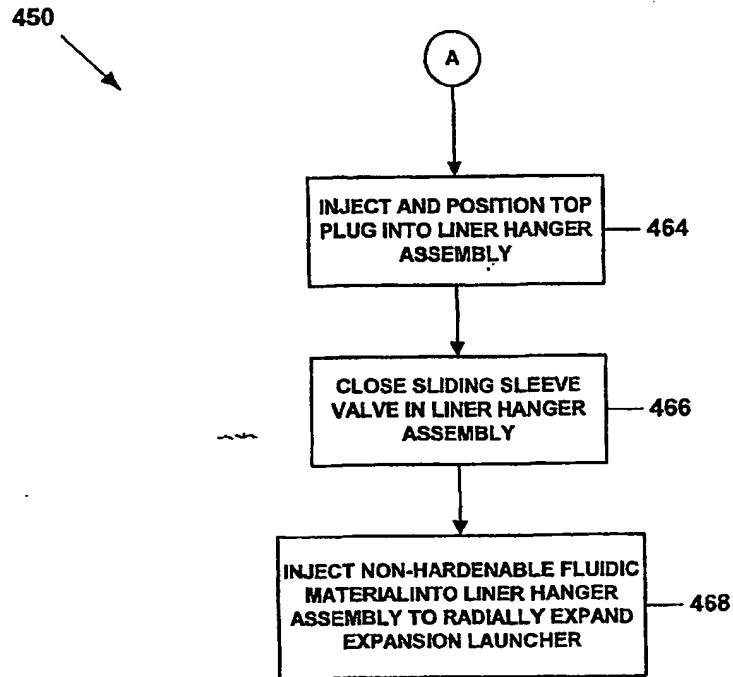
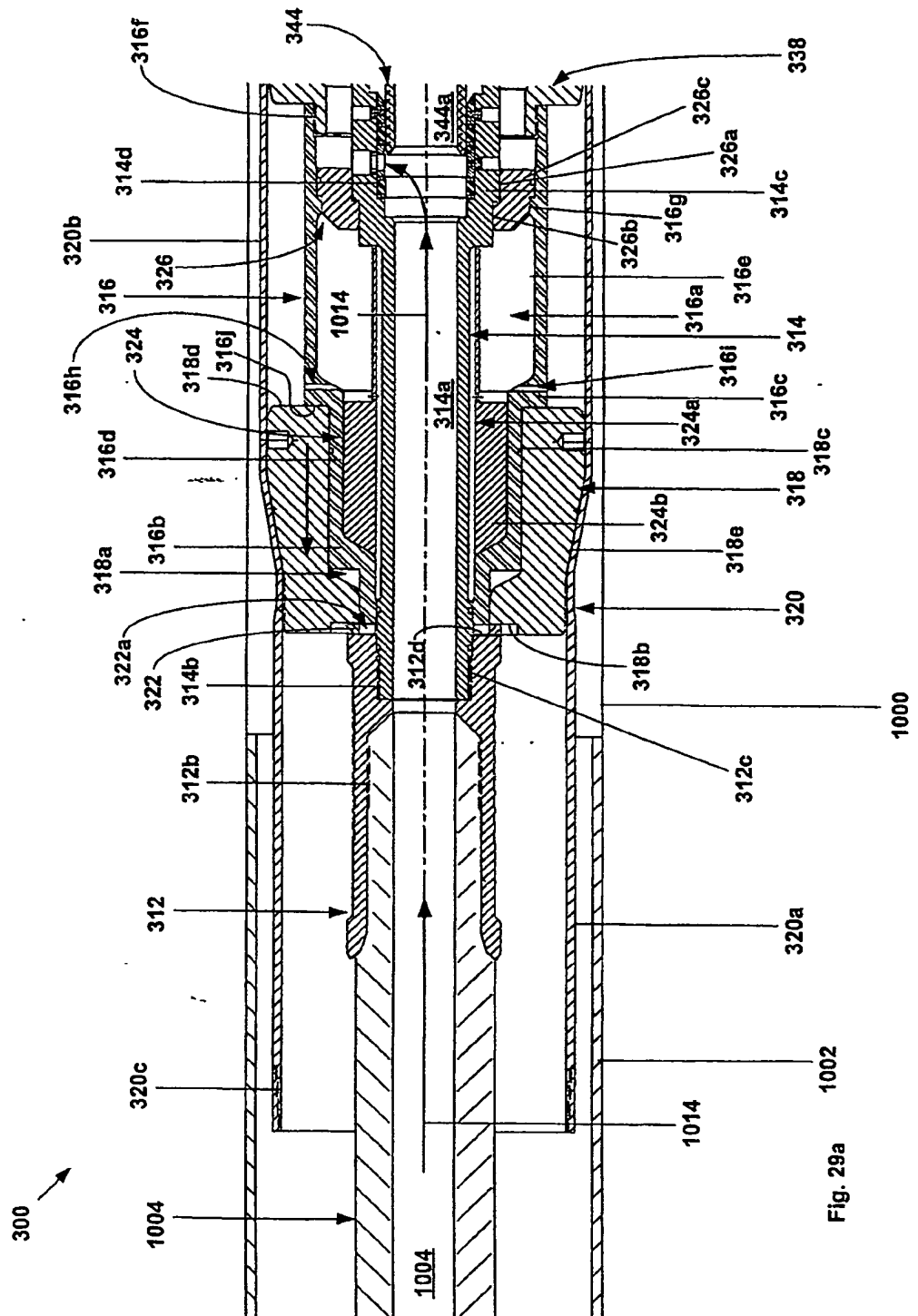
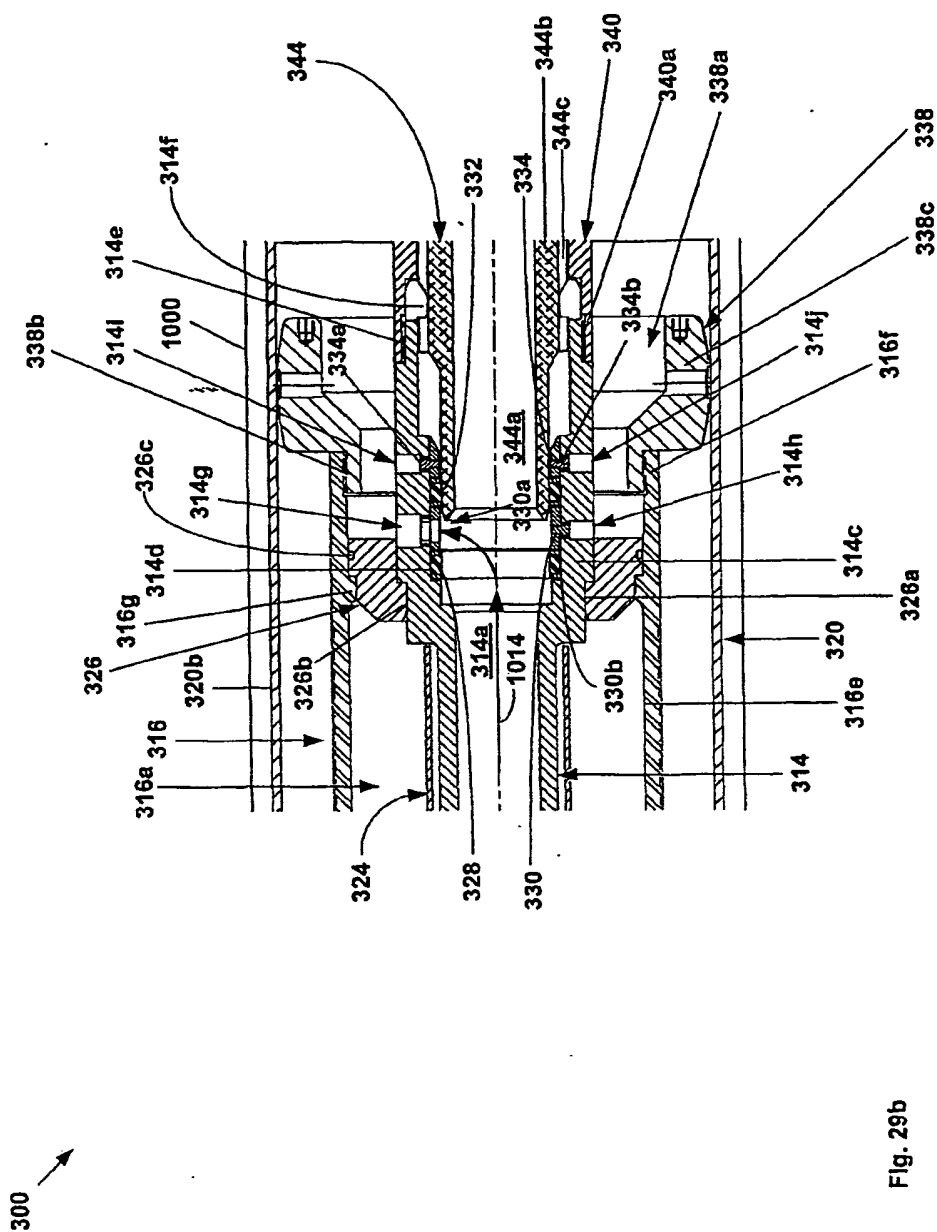
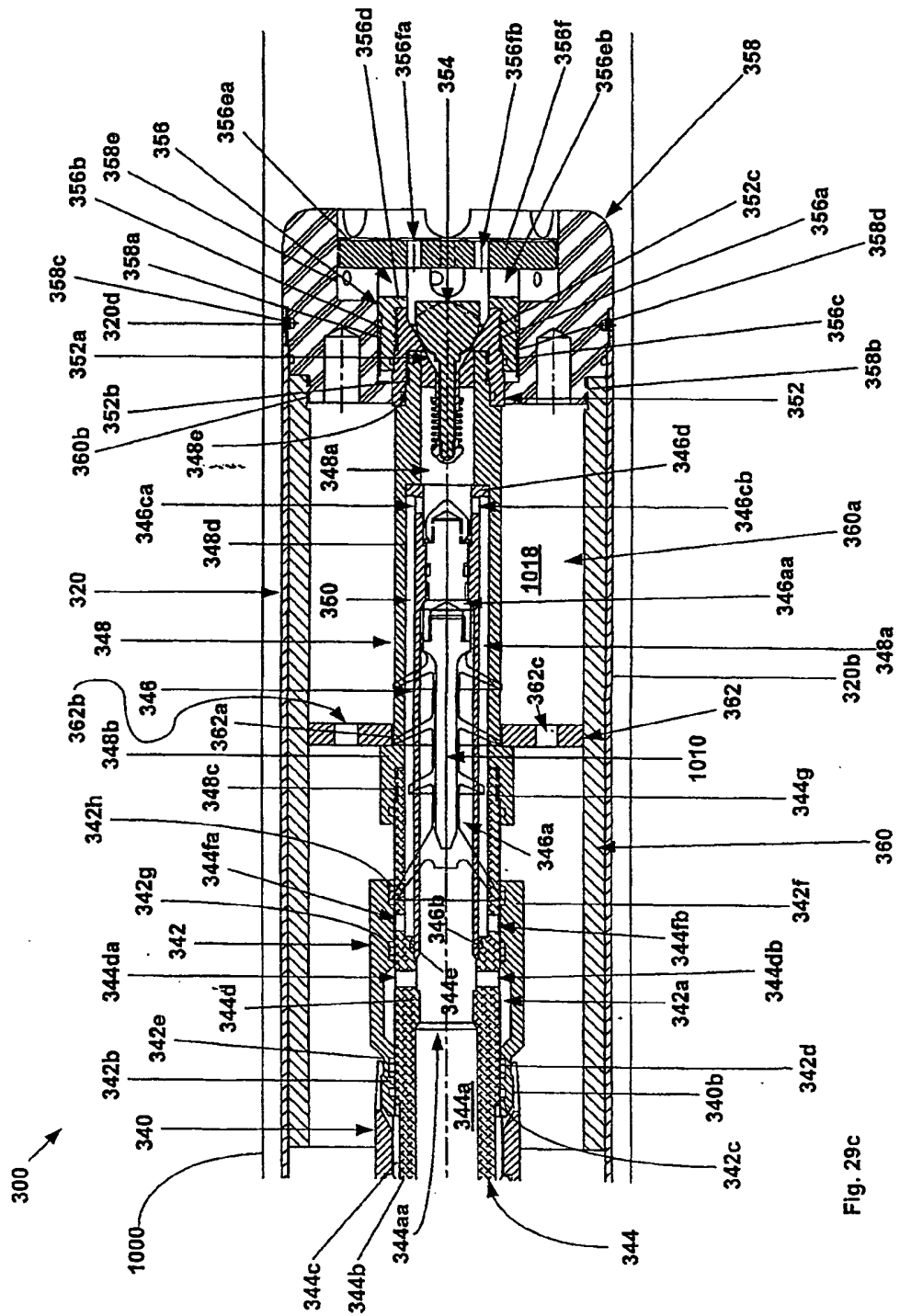


Fig. 28b




$$84/100$$



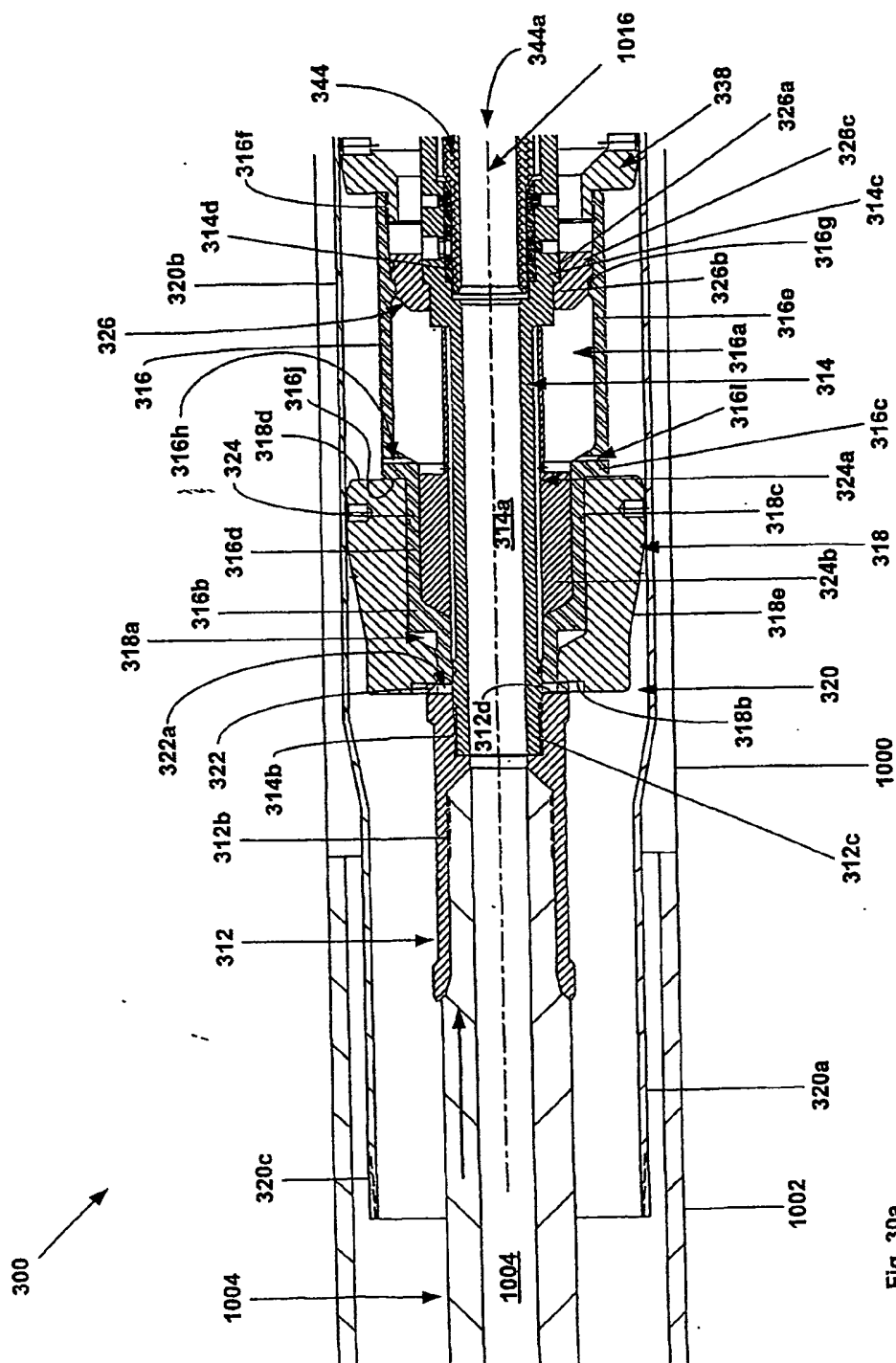


Fig. 30a

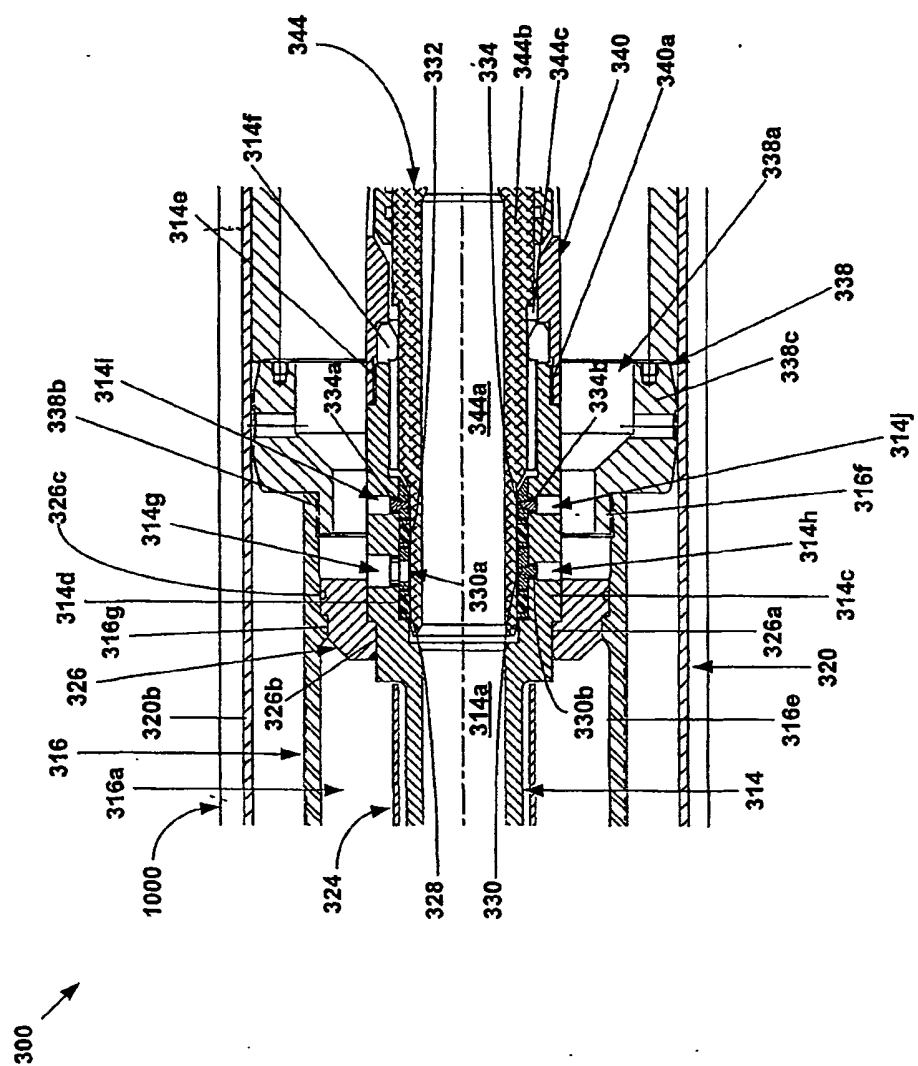


Fig. 30b

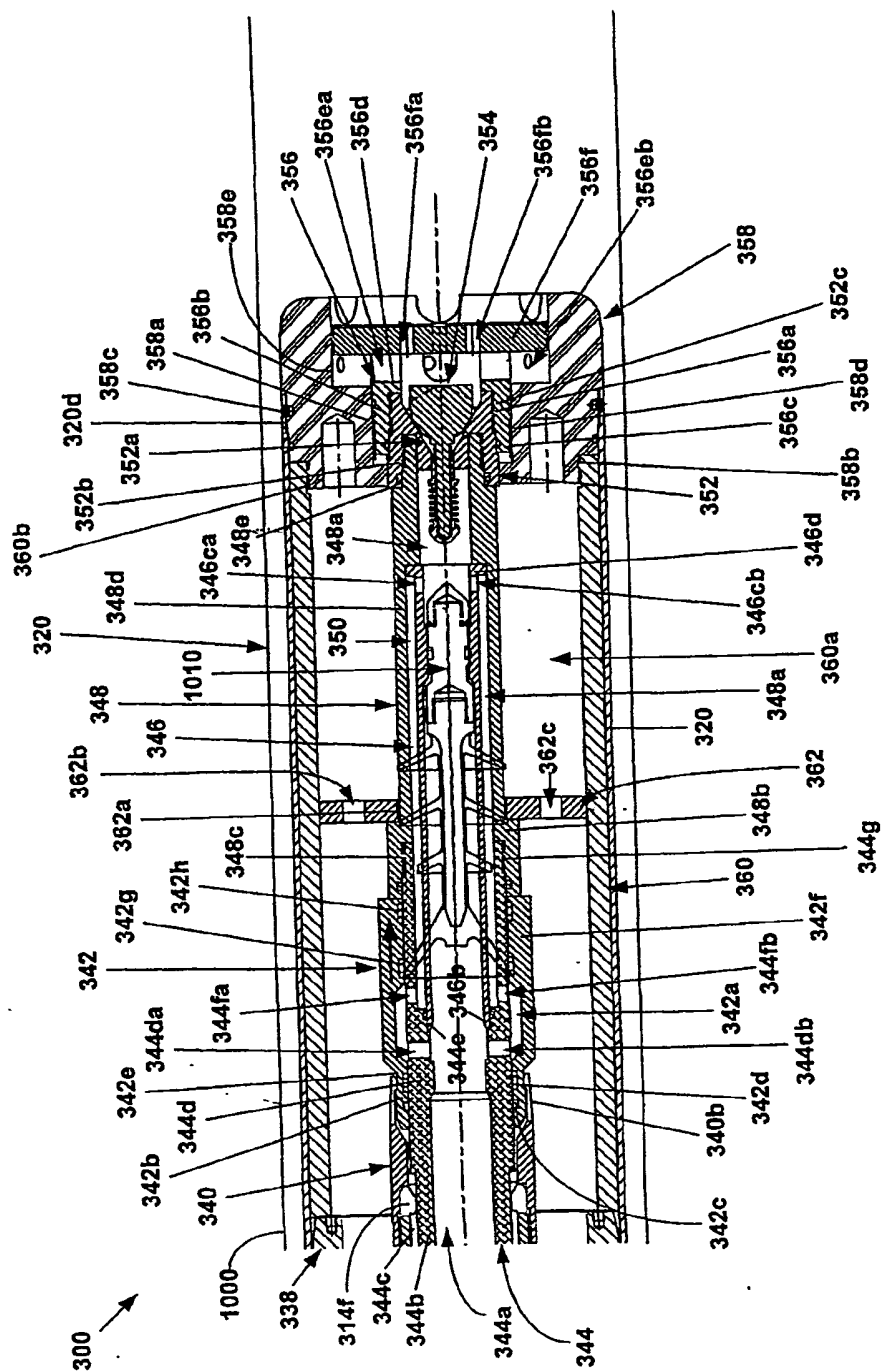


Fig. 30c

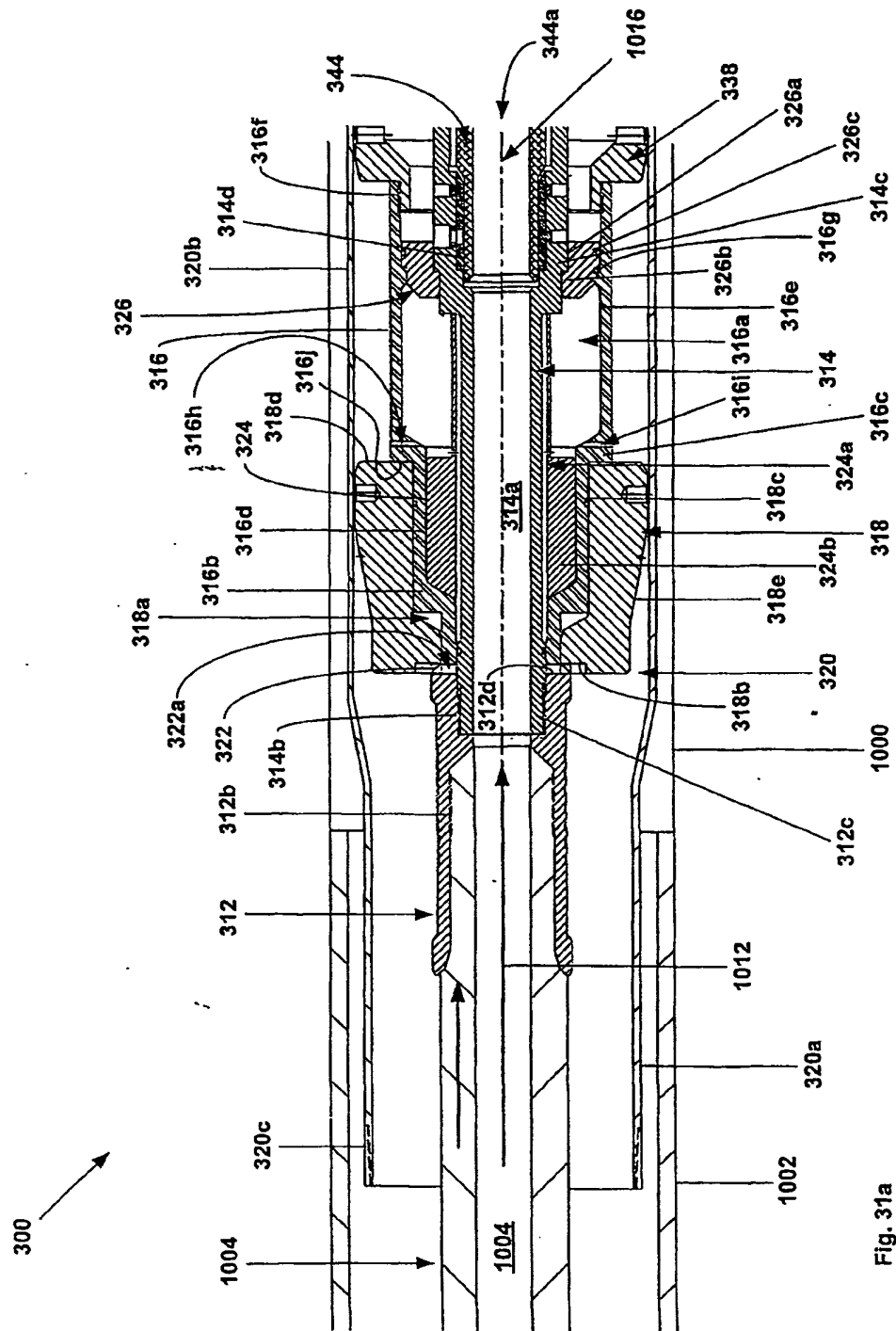


Fig. 31a

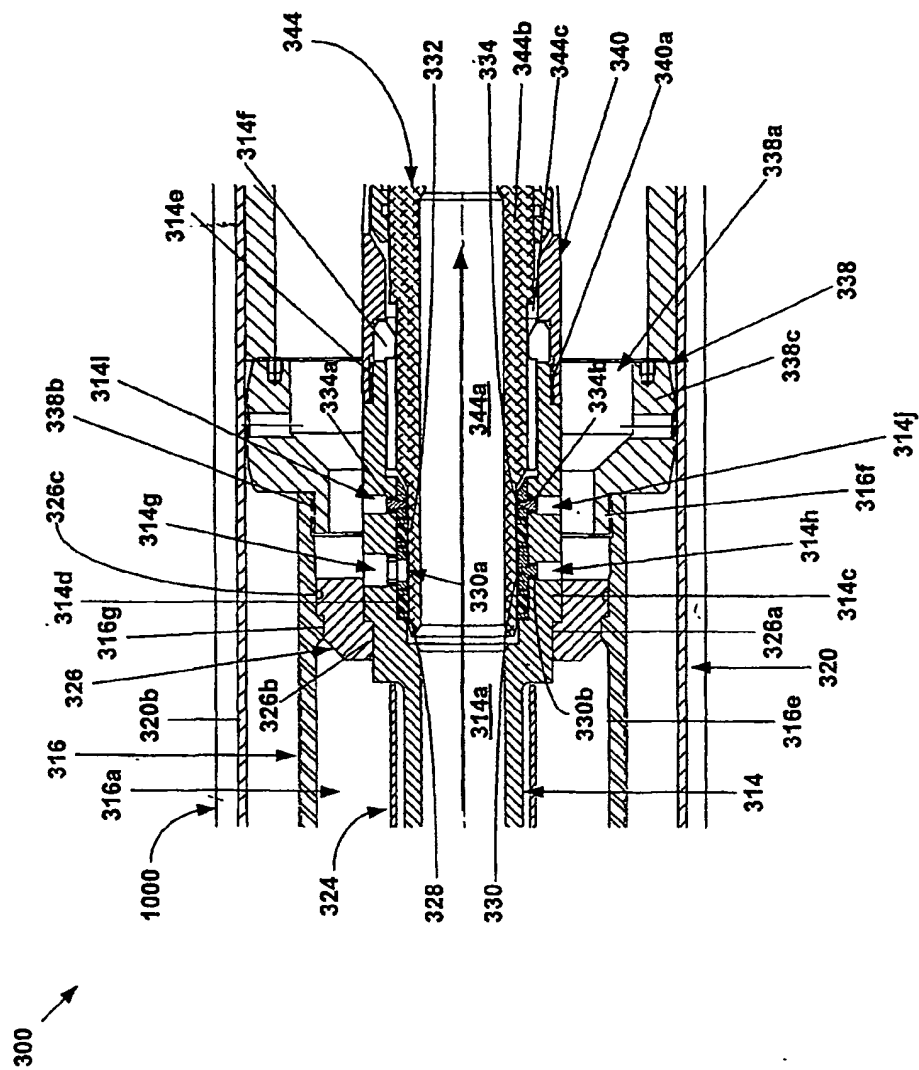


Fig. 31b

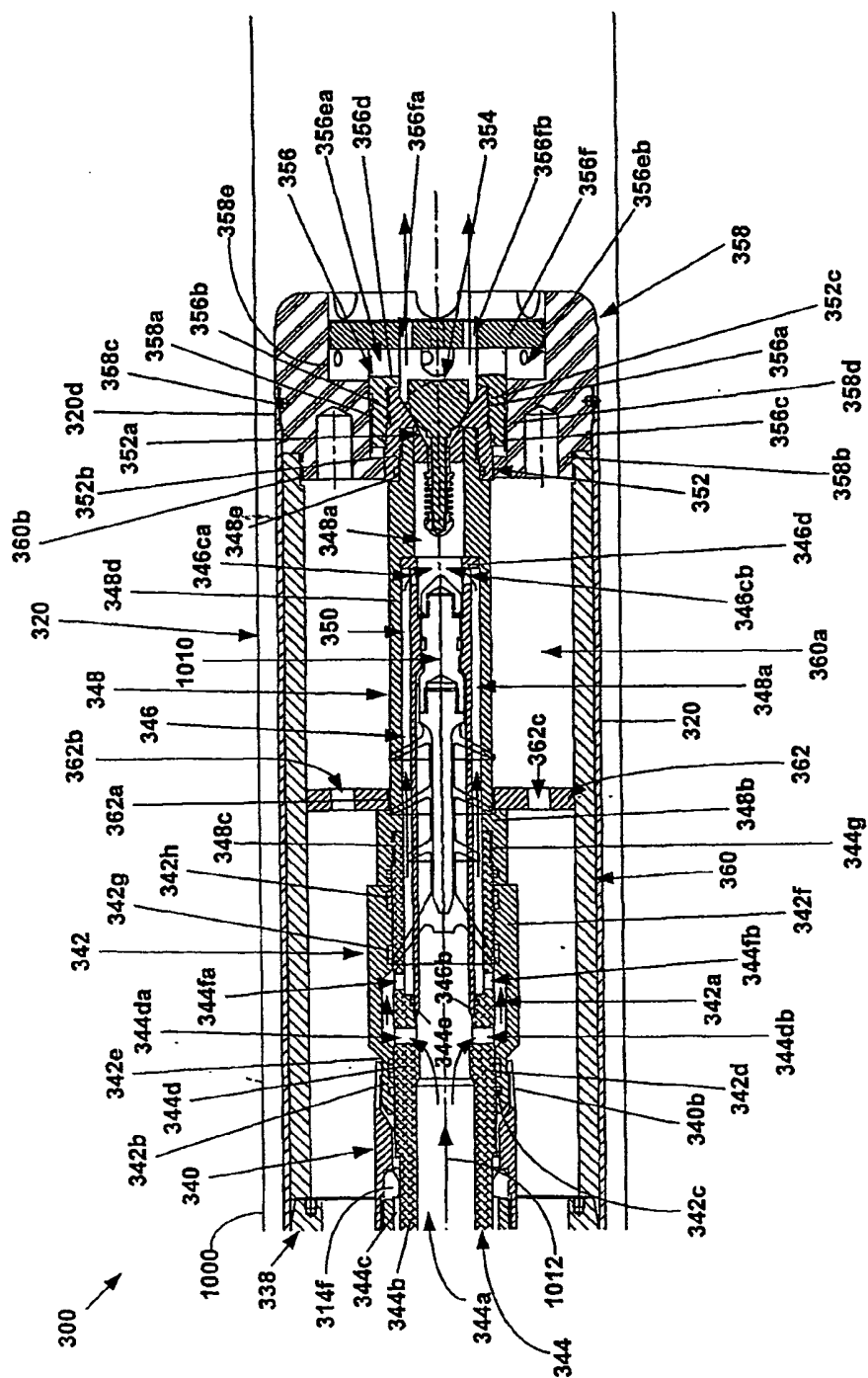


Fig. 31c

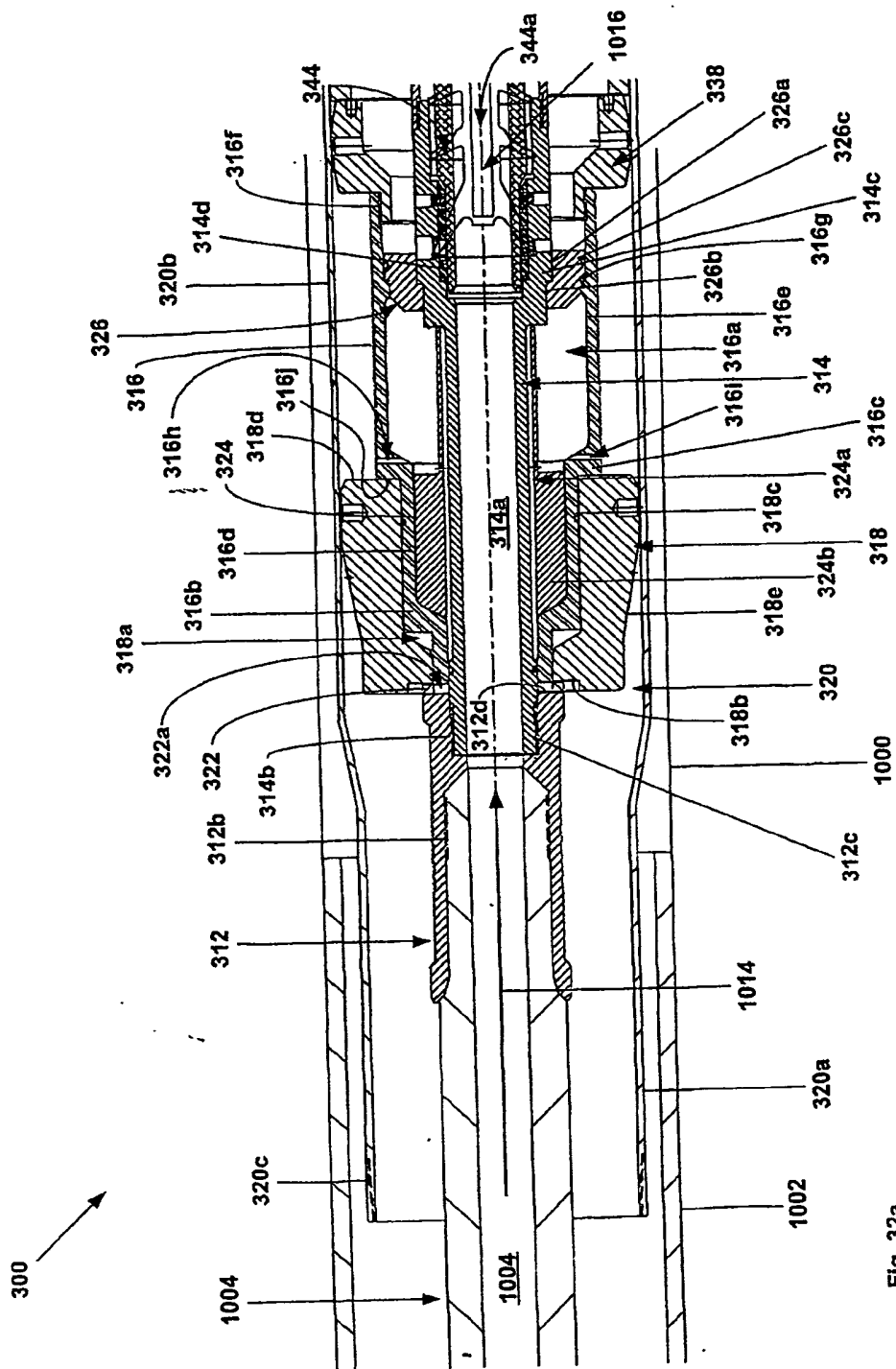


Fig. 32a

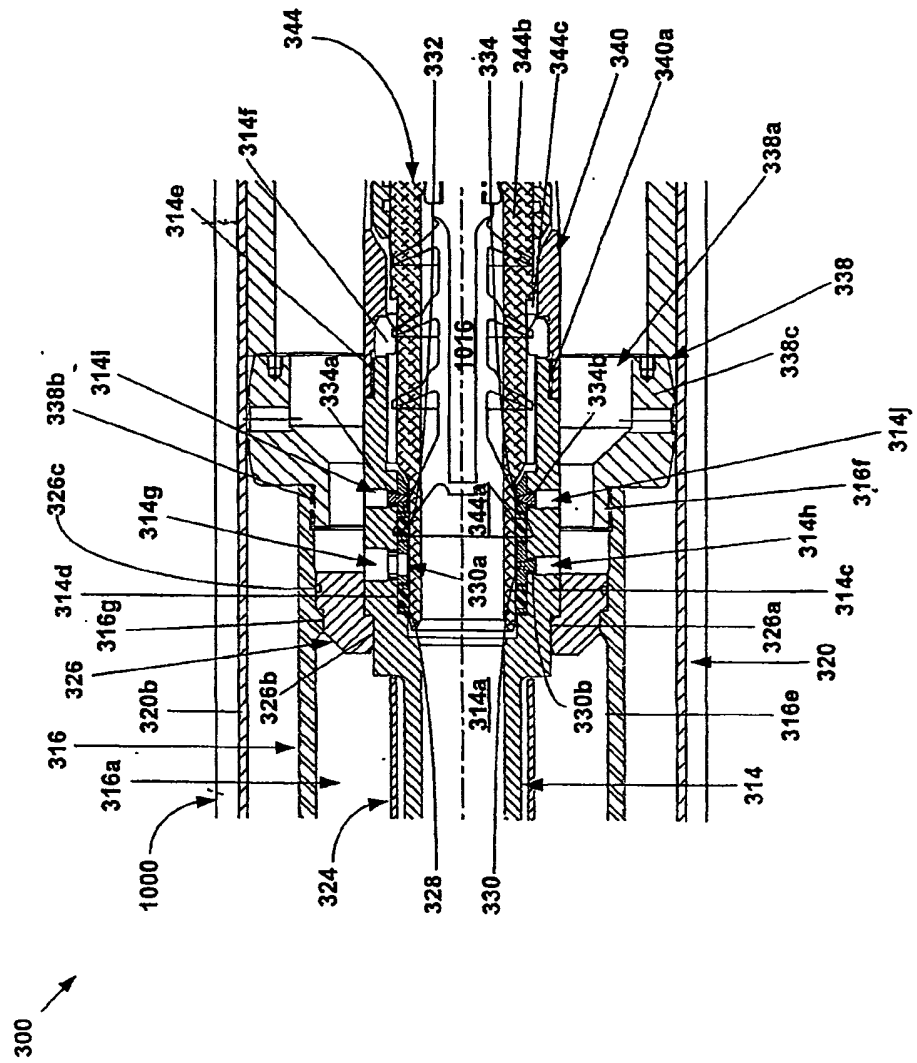


Fig. 32b

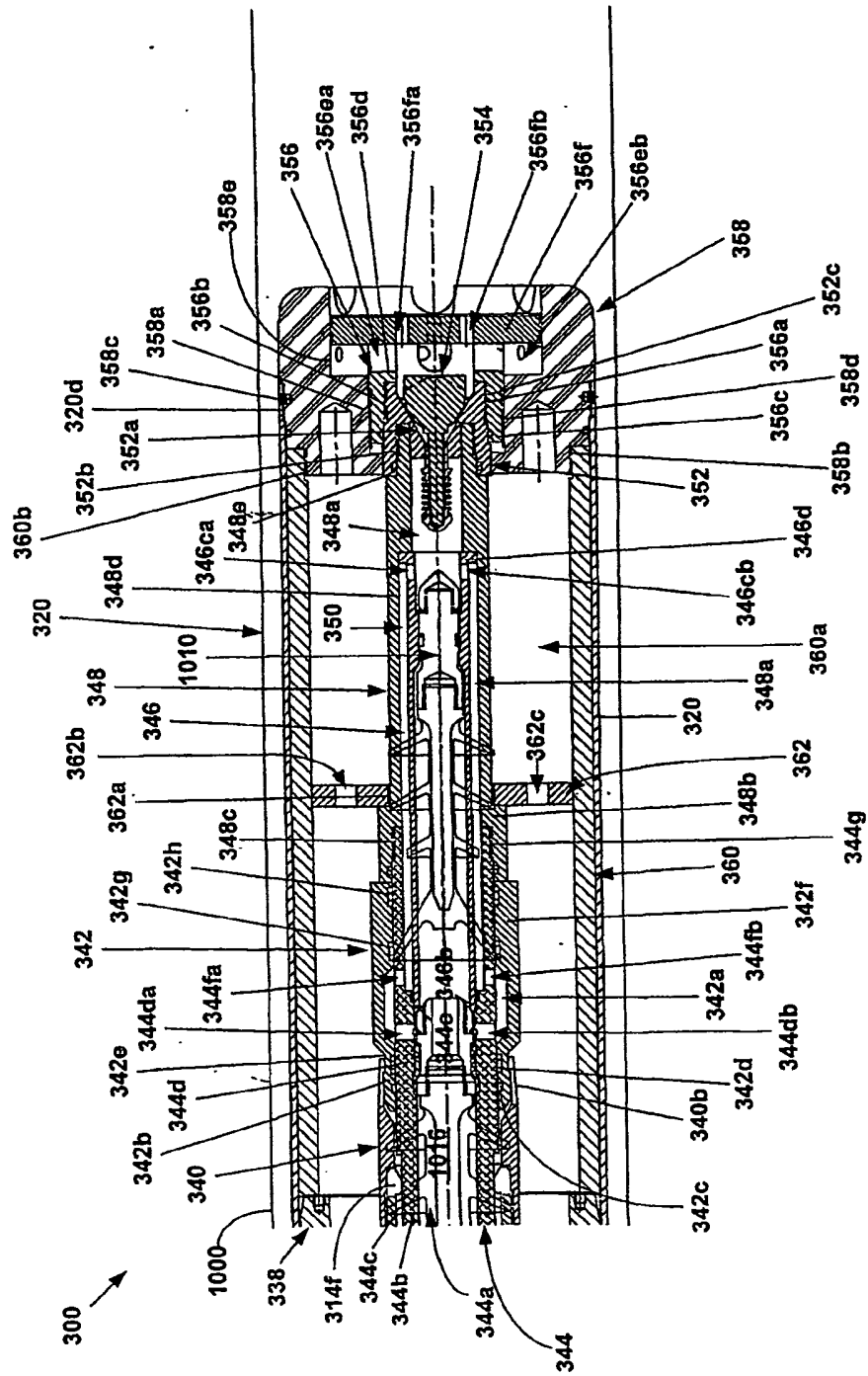


Fig. 32c

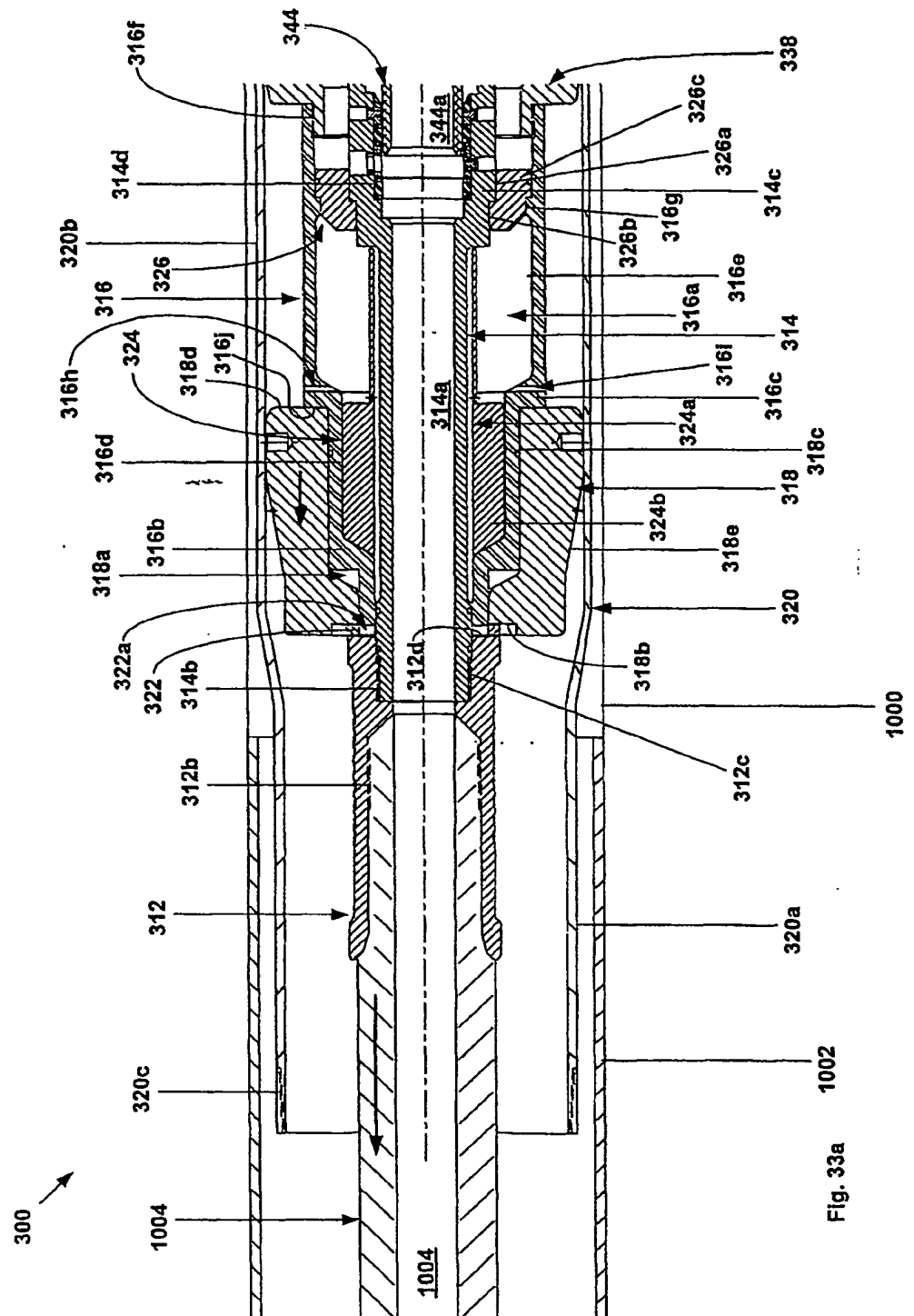


Fig. 33a

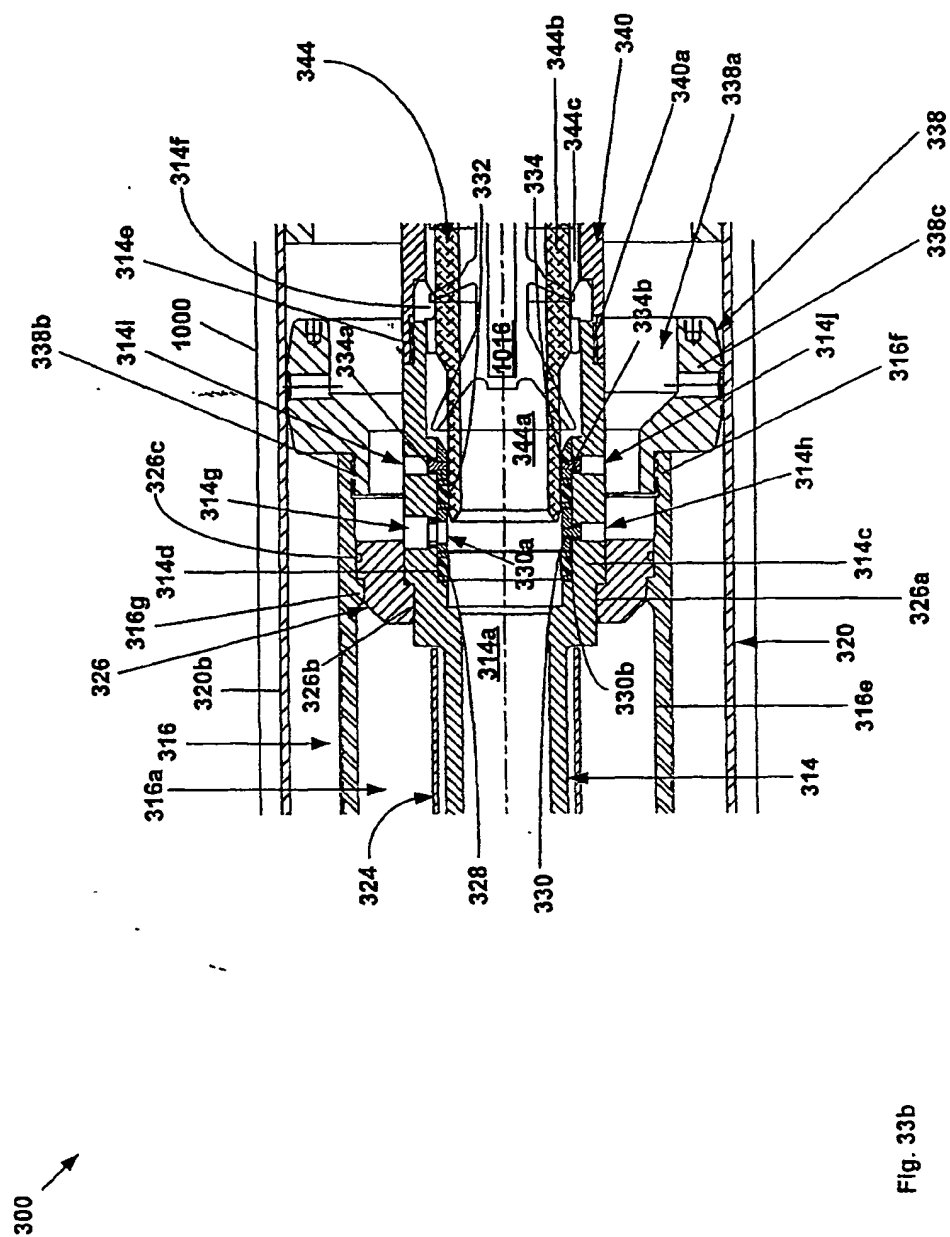


Fig. 33b

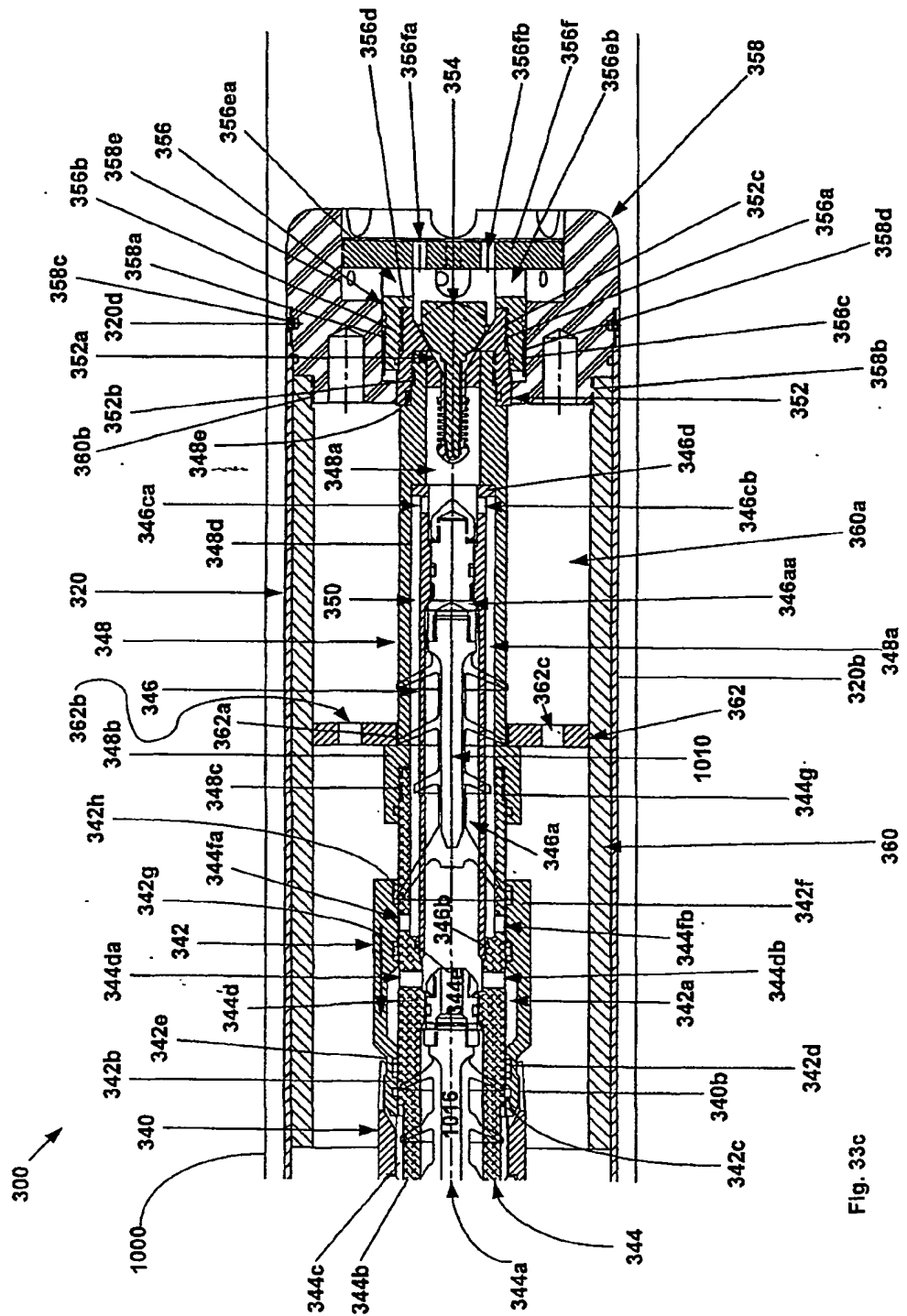
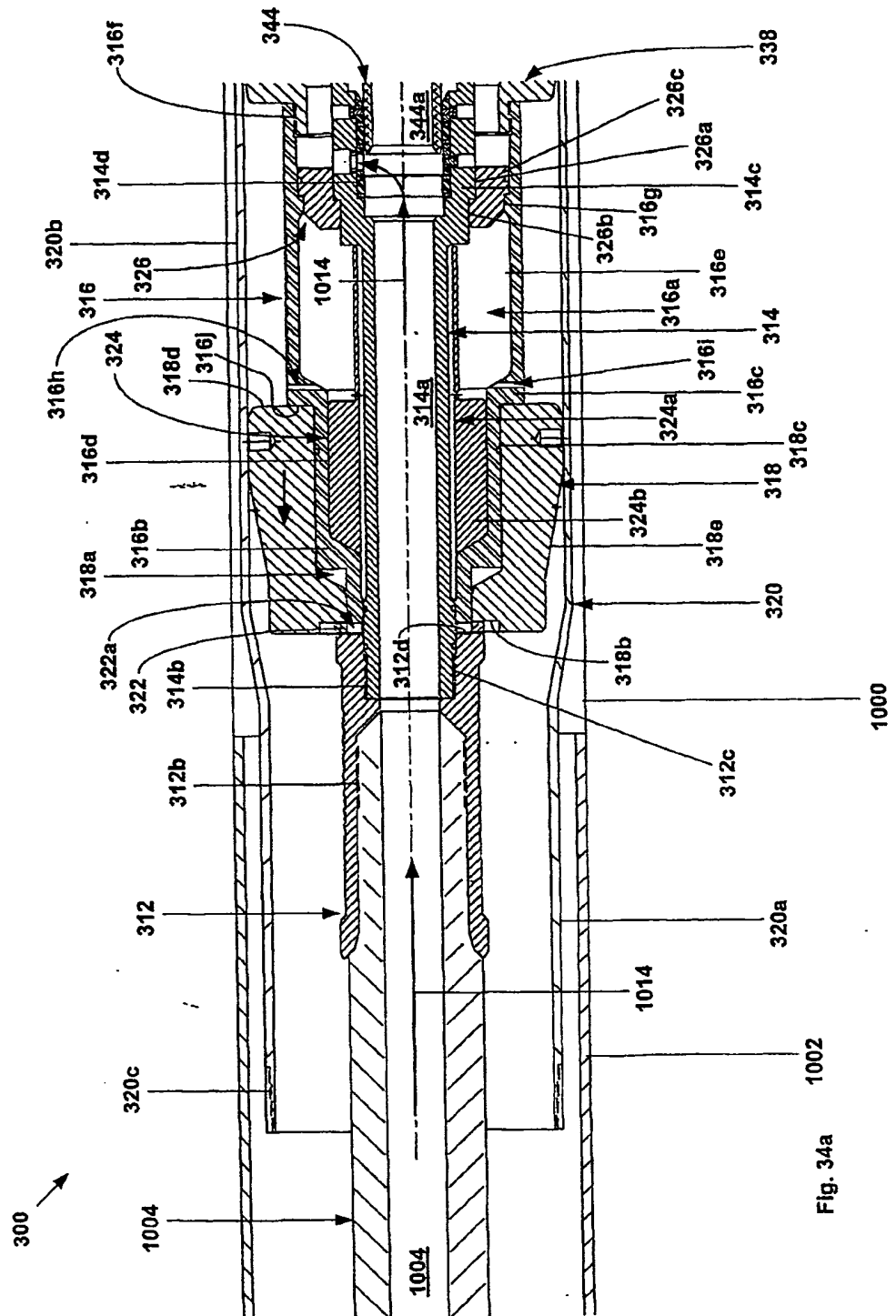
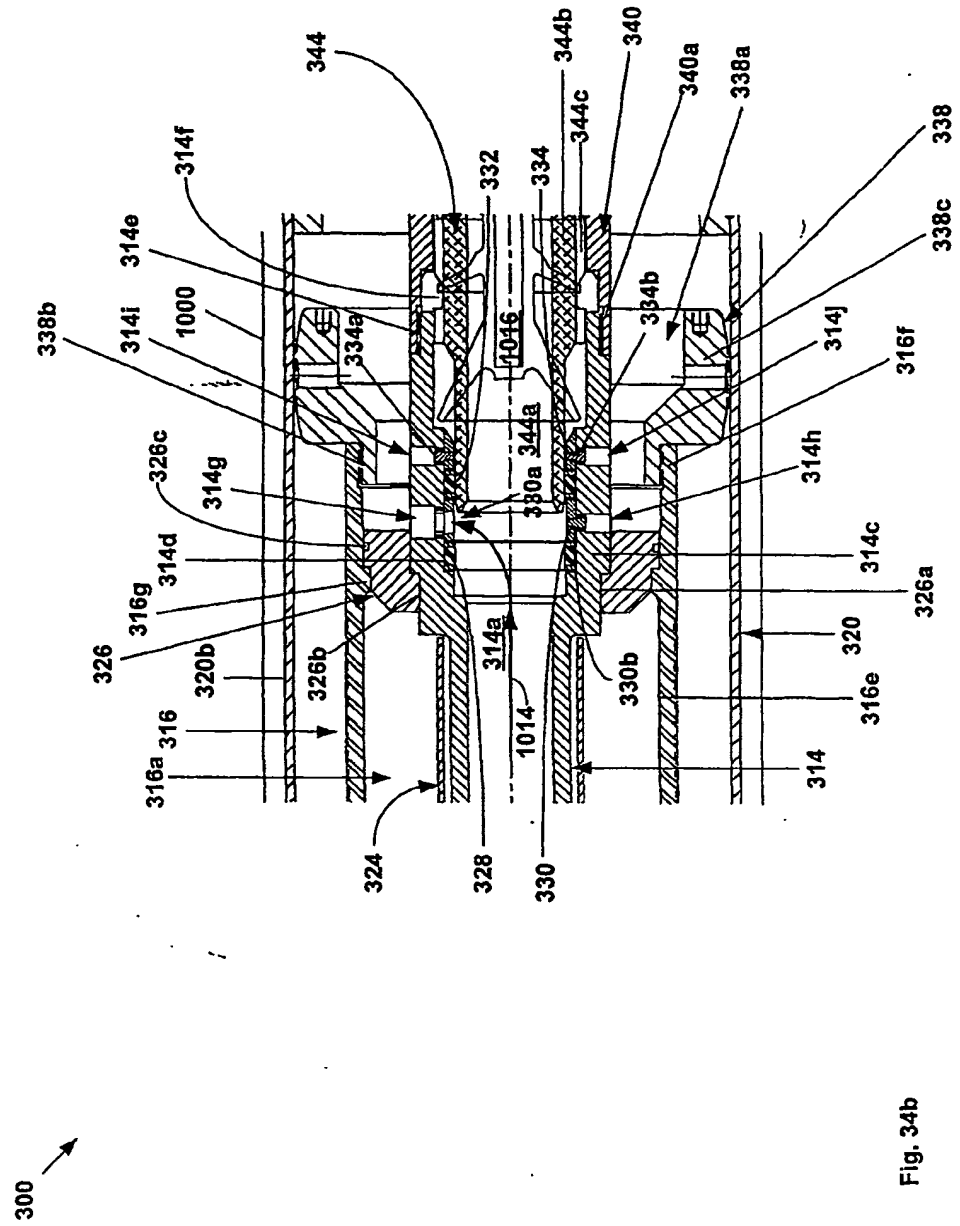


Fig. 33c





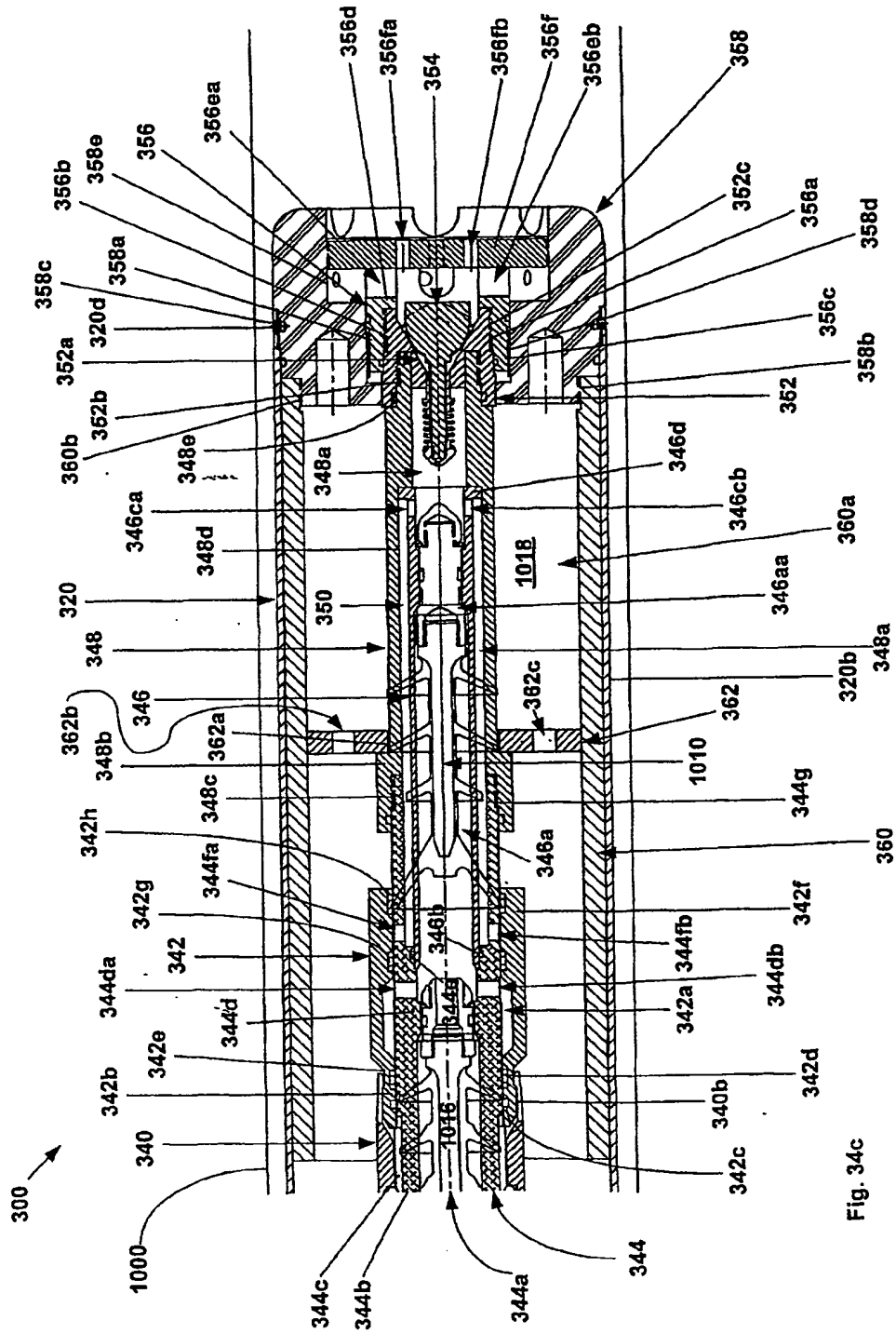


Fig. 34c

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/28960

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : E21B 23/00, 33/14

US CL : 166/277, 382, 177.4, 206, 207, 242.2

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 166/277, 382, 177.4, 206, 207, 242.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,718,288 A (BERTET et al) 17 February 1998 (17.02.1998), Figures 3B, 3C and 6-6C.	18, 19, 45 and 46
A	US 3,477,506 A (MALONE) 11 November 1969 (11.11.1969), Figures 1-7.	1-54
X	US 5,337,823 A (NOBILEAU) 16 August 1994 (16.08.1994), Figures 8-12 and column 12, line 56 through column 13, line 6.	18 and 45
A	US 5,667,011 A (GILL et al) 16 September 1997 (16.09.1997), see the entire patent.	1-54
A	US 5,901,789 A (DONNELLY et al) 11 May 1999 (11.05.1999), Figures 1-6.	1-54
A	US 6,012,523 A (CAMPBELL et al) 11 January 2000 (11.01.2000), see the entire patent.	1-54

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

28 November 2001 (28.11.2001)

Date of mailing of the international search report

22 JAN 2002

Name and mailing address of the ISA/US

Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703)305-3230

Authorized officer

Hoang Dang

Telephone No. 703-308-2168

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/28960

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐
☐

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/28960

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-17, 20-44 and 47-54, drawn to either a method or apparatus for forming a wellbore casing within a borehole within a subterranean formation or a method or apparatus for coupling an expandable tubular member to a preexisting structure.

Group II, claim(s) 18, 19, 45 and 46, drawn to an apparatus for forming a wellbore casing in a borehole in a subterranean or an apparatus for coupling an expandable tubular member to a pre-existing structure.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: The special technical feature for the claims of Group I is the arrangement including valves and fluid passages within the running tool which allows the tubular member to be expanded and cemented. The special technical feature of the claims of Group II is the combination in a single downhole tool of a means for expanding a tubular member and a means for injecting a hardenable fluidic sealing material into an annulus between the expandable tubular member and the wellbore.

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